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TABLES OF DIELECTRIC MATERIALS, VOL V

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LABORATORY FOR INSULATION RESEARCH
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MA

APRIL 1957

FINAL REPORT

MATERIALS DIRECTORATE
WRIGHT LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AFB OH 45433-7734

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13. ABSTRACT (Maximum 200 words)

This report is a compilation of dielectric materials properties. It was originally published in April 1957, by the Laboratory for Insulation Research, Massachusetts Institute of Technology. The report includes (1) dielectric constant and loss tangent data as a function of temperature and frequency, (2) low field strength data at fixed temperatures as a function of frequency, hysteresis loops and saturation magnetization for ferromagnetic dielectrics and (3) attenuation characteristics of ferrites, conducting ceramics and plastics, carbon-plastic mixtures and magnetic-plastic mixtures.

14. SUBJECT TERMS
DIELECTRIC CONSTANT, LOSS TANGENT, FREQUENCY, TEMPERATURE SATURATION MAGNETIZATION

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ERRATA

Tables of Dielectric Materials, Vol. V

Page viii, line 6, for "0.1" read "< 0.1."

" x, line 8, for "0.005" read " < 0.005"; for "1" read " > 1"; line 10, for "0.002" read " < 0.002."

" 2, line 3 from bot., for "1.3," "1.7," "4.8" read "13," "1.3," "1.7."

" 4, line 11, for "0.004" read "0.044"; line 13, delete "268" and "21.4."

" 5, lines 6 and 7, raise to correspond with "Corning 7910."

" 7, line 3 from bot., for ".3.68" read "3.68."

" 8, line 4, for "-275" read "275"; line 5, for "33.27" read "3.27."

" 11, line 6, for "--31" read "31."

" 13, line 3, for "to film" read " $\perp$ to film"; lines 9 and 11 from bottom of Table, change single to double asterisks.

" 14, line 8, for "4.84" read "3.84."

" 161 and 165, "Note," for "K_m" read "κ^*_m."

" 174, line 2, delete " "Fe."

" 175, line 2, for "Cerqmivs" read "Ceramics."

" 245, line 9, first column, for "Iv-58" read "IV-58."

" 247, line 19, second column, for "159-175" read "159-176."

" 249, line 6 from bot., first column, for "133-139, 142-158, 177-180" read "133-136, 138, 139, 142-158, 177, 179, 180"; second column, line 2, for "V-140, 141" read "V-137, 140, 141"; line 3, for "176, 181, 182" read "176, 178, 181, 182."

Laboratory for Insulation Research
Massachusetts Institute of Technology

In addition to the printed errata the following errors have come to our attention:

Page 6, Boron nitride, add these tan δ's:

f	tan δ
$1x10^2$	10.3
$1x10^3$	6.5
$1x10^4$	4.2
$1x10^5$	3
$1x10^6$	2.0
$1x10^7$	1.4
$1x10^8$	0.92

Page 39, tan δ at $f = 10^{10}$ should be:

T^oC	tan δ
26	0.00026
116	0.00029
206	0.00034
302	0.00044
412	0.00058
457	0.00069
499	0.00080

Page 52, "Wesgo" Al-300:

$f = 9.5x10^9$ instead of $f = 9.5x10^{10}$;

tan δ scale should read:

0.0006

0.0004

0.0002

TABLES OF DIELECTRIC MATERIALS

VOLUME V

Laboratory for Insulation Research
Massachusetts Institute of Technology
Cambridge, Massachusetts

Contract Nonr-1841(10)

April, 1957

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Tables of Dielectric Materials

Volume V

Laboratory for Insulation Research
Massachusetts Institute of Technology
Cambridge, Massachusetts

During World War II the Laboratory for Insulation Research assumed, in addition to other tasks, the responsibility of acting as a clearing house for dielectric information. It developed measurement techniques over wide ranges of frequency and temperature, provided data on materials of strategic importance and summarized the results in the "Tables of Dielectric Materials."

Volumes I and II were issued during the war. The termination of hostilities, however, did not end our obligation. Government and Industry relied on these data, and the idea had become entrenched that materials of general interest could be measured in our laboratory free of charge in return for background information required for the defense effort. Volume III was issued in 1948, and our clearing house activity stepped up when the outbreak of the Korean war emphasized the precariousness of the political situation. Volume IV, released in January 1953, summarized in expanded measurements all materials of importance at that time and was made generally available as Appendix to the book "Dielectric Materials and Applications" (Technology Press and John Wiley and Sons, New York, 1954). In the interim periods, the accumulating information aided Government agencies and industrial laboratories in the selection and development of dielectrics under Government contracts.

Since 1953 the missile age has arrived with its demands for high-temperature dielectrics. At the same time the concepts of "Molecular

Engineering," on which the Laboratory for Insulation Research was founded, are rapidly becoming public property: dielectrics are being made to order for an increasing number of new devices. These trends are reflected in Volume V of the "Tables" by extension to high-temperatures (Sec. III), ferromagnetics (Sec. IV) and attenuator characteristics (Sec. V).

Like its predecessors, Volume V is a storage bin of practical information, ill-adapted for theoretical analysis. Here are radome materials and glass cloth; jet fuel and compressed gases; Scotch tape, Kraft paper and Sauereisen cement, to mention only some of the more outlandish representatives. Here is demonstrated that impure raw materials cause inferior high-temperature performance and that overheating produces rapid degradation. There are also examples of beneficial action of heating in driving out detrimental moisture and volatile compounds. Trends are revealed for the development of better materials, and faulty manufacturing practices are exposed for remedial action. Our task here is an unbiased presentation of data, which leaves the users of the "Tables" free to draw their own conclusions.

A true dielectric analysis of materials requires a different approach: accurately defined materials; controlled variation of composition and structure; careful investigation of the influence of manufacturing parameters; and a comparison of the properties of multicrystalline materials with those of single crystals. This arduous task has been started in our laboratory for ferromagnetic semiconductors by a careful ceramics study of square-loop materials (G. Economos, Tech. Rep. 78, May, 1954; J. Amer. Ceram. Soc., July through November, 1955); in an extensive broad-band investigation of ferrites from d.c. to the ultraviolet (A. von Hippel, W.B. Westphal and P.A. Miles, "Dielectric Spectroscopy of Ferromagnetic Semiconductors," Tech. Rep. 97, July, 1955, revised for Revs. Mod. Phys., July, 1957);

and by a detailed analysis of a special type of relaxation spectrum identified in ferrites (D. J. Epstein, "Domain-Wall Relaxation in Ferrites," Papers presented at the Conference on Magnetism and Magnetic Materials, Boston, Mass., Oct. 16-18, 1956, Amer. Inst. Elec. Engrs. T-91, 1957, p. 493).

The development of "Dielectric Spectroscopy" into a powerful tool of nondestructive analysis for the whole field of "Molecular Science and Engineering" should receive top priority in the use of our resources from now on. We intend therefore to terminate the service "Tables of Dielectric Materials" by the end of this year; a Volume VI will summarize ferroelectric and residual data. We hope that some independent and unbiased agency will continue this work of evaluating materials and acting as a clearing house for dielectric information.

Our venture was made possible through the ingenuity and indefatigable efforts of Mr. W.B. Westphal, group leader of the dielectric measurements group. Mrs. Barbara Beal East, his able co-worker for several years, measured most of the low field-strength data, supported in recent months by Mrs. Rhoda Yarkin. Mrs. Ann Miller and Frank Bispham gave technical assistance, and Miss Aina Sils and John Mara were of great help in the preparation of the final manuscript. The hysteresis data of Sec. IV were obtained by B. Frakiewicz with F. Bispham and under the general direction of Prof. D.J. Epstein, group leader of the ferromagnetics group.

The Laboratory for Insulation Research has operated under the joint sponsorship of the Navy Department (Office of Naval Research), the Army Signal Corps, the Air Force (Air Matériel Command), and the Ordnance Materials Research Office for many years in an atmosphere of mutual trust and understanding; we gratefully acknowledge this support.

A. von Hippel

Dielectric Parameters

1. ϵ'/ϵ_o, the dielectric constant or permittivity relative to vacuum, also designated in the literature as K, κ_e, κ', ϵ, ϵ', D.C., etc.
2. κ', same as ϵ'/ϵ_o.
3. tan δ, the dielectric loss tangent or dissipation factor, also designated in the literature as DF, 1/Q, and when losses are low (0.1) as power factor or cos θ.
4. tan δ_d or tan δ_e, same as tan δ.
5. ϵ''/ϵ_o, the dielectric loss factor relative to vacuum, also designated in the literature as κ'', ϵ''. L.F., etc.
6. κ'', same as ϵ''/ϵ_o.
7. μ'/μ_o, the magnetic permeability relative to vacuum, also designated in the literature as μ', μ_R, μ_o, κ'_m.
8. κ'_m, same as μ'/μ_o.
9. tan δ_m, the magnetic loss tangent, also designated in the literature as 1/Q.
10. μ''/μ_o, the magnetic loss factor in analogy to the dielectric loss factor; also designated in the literature as μ'', μ_I, κ''_m.
11. κ''_m same as μ''/μ_o.
12. $\kappa''/(\kappa'_m)^2$, a figure of merit for core materials, also designated in the literature as loss factor, $1/\mu'Q$.
13. tan δ_t, the total loss tangent, the sum of tan δ_d plus tan δ_m. Relations between parameters are discussed in Vol. IV. The ferromagnetic sections use the parameter κ''_m instead of tan δ_m, which becomes clumsy in the frequency region where κ' is close to zero or negative.
14. ρ, the a-c volume resistivity in ohm-cm.
15. σ, the a-c volume conductivity in mho/m.
16. α, the attenuation constant for propagation in free space in decibel per cm.

17. β/β_o, the phase constant relative to vacuum for propagation in free space.
18. $|Z|$, the magnitude of the intrinsic impedance relative to vacuum for propagation in free space.
19. θ, the angle of the intrinsic impedance.

Measurements and Accuracy

The measurements have been made, in general, on only one batch of the material and refer, unless otherwise specified, to samples measured at room temperature (25 to 26^{o}C) and room humidity (30 to 50% R.H.). Due to the wide variety of materials and improvements in techniques, no figures of general validity can be given concerning the accuracy of these measurements. For ϵ'/ϵ_o, the nominal accuracy is $\pm$2%; the accuracy trends are toward $\pm$1% for rigid, low-loss materials (tan δ 0.005) and $\pm$5% for high-loss materials (tan δ 1). For tan δ_d, the nominal accuracy is $\pm$5%; for high-loss materials, the error may be $\pm$10%. For very low-loss materials (tan δ 0.002), the accuracy is $\pm$0.0001 when the losses are given as multiples of 0.0001. When the loss is expressed in multiples of 0.00001, the error may be $\pm$0.00003. For μ'/μ_o, the nominal accuracy is $\pm$5%, for tan δ_m, $\pm$10%.

Field strengths. The linear dielectrics, those normally not field-strength sensitive, were measured at field strengths of approximately 50 volts per cm. in the frequency range 10^2 to 10^8 c/s and at lower field strengths at higher frequencies.

The ferromagnetic materials, unless otherwise noted, were measured at field strengths in their linear region. The values thus measured are the initial permeability.

For laminates, which are in general not isotropic, the direction of the electric field is perpendicular to the plane of the laminate for frequencies in the range 10^2 to $3x10^8$ c/s and parallel for higher frequencies unless otherwise specified.

Some metal-loaded materials have been measured which are slightly diamagnetic, but are not sufficiently homogeneous for precise separation of μ^* and ϵ^*. For these the product of dielectric constant and permeability and the sum of the loss tangents is given.

I. Tabulated Dielectric Data at Room Temperature (25 to 26°C)

Values of tan δ are multiplied by 10^4; frequency given in c/s.

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
A. Solids, inorganic															
1. Crystals															
Aluminum oxide, sapphire[a]	ϵ'/ϵ_o	9.53	9.53	9.53	9.53	9.53	9.53	9.53	9.53	----	----	----	----	9.5	
(field ⊥ optical axis)	tan δ	< 10	< 2	< 10	< 10	< 10	< 10	< 10	< 1	----	----	----	----	< 20	
(field ‖ optical axis)	ϵ'/ϵ_o	11.53	11.53	11.53	11.53	11.53	11.53	11.53	11.53						
	tan δ	< 10	< 2	< 10	< 10	< 10	< 10	< 10	< 1						
Barium titanate, hexagonal[b]	ϵ'/ϵ_o	-----	----	59											
(field ⊥ optical axis)	tan δ	----	----	< 40											
(field ‖ optical axis)	ϵ'/ϵ_o	249	247	246	244										
	tan δ	62	41	27	15										
Calcium fluoride[b]	ϵ'/ϵ_o	----	6.82												
	tan δ	----	< 10												
Carbon, diamond[c]	ϵ'/ϵ_o	----	----	5.68											
	tan δ	----	----	< 2											
Cesium bromide[b]	ϵ'/ϵ_o	6.62	6.62	6.62	6.62										
	tan δ	2	< 1	< 1	< 2										
Cesium iodide[b]	ϵ'/ϵ_o	5.97	5.97	5.97	5.97										
	tan δ	10	6	4	< 2										
Potassium chloride[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	4.75			
	tan δ	----	----	----	----	----	----	----	----	----	----	1.1			
Thallium chloride[b]	ϵ'/ϵ_o	----	31.9												
	tan δ	----	380												
2. Ceramics															
a. Aluminas															
"AlSiMag" 491 (blue)[e]	ϵ'/ϵ_o	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	----	----	7.73			
	tan δ	11	9.8	9.5	9.4	7.4	5.8	7.8	9.2	----	----	13			
"AlSiMag" 513 (pink)[e]	ϵ'/ϵ_o	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	----	----	7.97			
	tan δ	9.7	22	18	9.2	7.9	11	15	16	----	----	15			

a. Linde Air. b. Lab. Ins. Res. c. Data of S. Whitehead and W. Hackett, Proc. Phys. Soc. 51, 173 1939. d. Harshaw. e. Amer. Lava (dry values).

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I A 2a. Aluminas (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"AlSiMag" 544[a**]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	5.80	----	----	5.80
	tan δ	----	----	----	----	----	----	----	----	----	----	10	----	----	10
"AlSiMag" 576[a]	ϵ'/ϵ_o	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	----	----	7.97			
	tan δ	10	7.5	5.5	4.2	3.4	4.0	6.4	7.9	----	----	15			
"AlSiMag" 614[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	10.0			
	tan δ	----	----	----	----	----	----	----	----	----	----	8			
Coors AL-100[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	6.47			
	tan δ	----	----	----	----	----	----	----	----	----	----	0.9			
Coors AI-200[b] (1954 sample)	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.78			
	tan δ	----	----	----	----	----	----	----	----	----	----	10.4			
Corning JD-40[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	8.25		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	38		
Corning JD-82[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.85			
	tan δ	----	----	----	----	----	----	----	----	----	----	18			
Corning JB-123[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.02			
	tan δ	----	----	----	----	----	----	----	----	----	----	20			
Corning WD-131[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.45			
	tan δ	----	----	----	----	----	----	----	----	----	----	25			
Corning JB-183[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	8.22		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	30		
Diamonite B-890[d]	ϵ'/ϵ_o	9.25	9.25	9.25	9.25	9.25	9.25	9.25	9.25	9.23	9.20	9.15*			
	tan δ	9	5.4	6.8	7	6	< 1	< 1	3	5.8	9.1	10*			
Diamonite P-3142[d]	ϵ'/ϵ_o	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.60	9.53	9.42	9.36			
	tan δ	3.3	1.8	1.4	< 1	1.5	4.5	4.2	2.5	4.0	6.0	15			
Diamonite P-3459[d]	ϵ'/ϵ_o	12.8	12.1	10.7	9.43	9.13	9.10	9.10	9.10	9.08	9.05	9.03			
	tan δ	290	577	953	585	120	1.3	1.7	4.8	4.8	8.0	15			

a. Amer. Lava (dry values). b. Coors (dry value). c. Corning. d. Diamonite.

*Freq. = $9.3x10^9$ c/s. **This data superceded on page 21.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I A 2a. Alumina (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
Diamonite P-3530-40[a]	ϵ'/ϵ_o	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.95	8.90	8.85	8.77			
	tan δ	7.8	5.4	4.6	3	2	8	8	8	8.5	10.9	15			
Frenchtown 6096[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	8.17					
	tan δ	----	----	----	----	----	----	----	----	13					
Frenchtown 7873[b,c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	6.60					
	tan δ	----	----	----	----	----	----	----	----	22					
General Ceramic ADH-211[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.93			
	tan δ	----	----	----	----	----	----	----	----	----	----	9.5			
Kearfott High Purity Alumina[e]	ϵ'/ϵ_o	9.40	9.40	9.40	9.40	----	----	----	----	----	----	9.40	9.40	----	9.4
	tan δ	3	< 2	< 2	< 5	----	----	----	----	----	----	1.8	1.5	----	1.7
"Sintox"[f]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	----	9.15	
	tan δ	----	----	----	----	----	----	----	----	----	----	----	----	16	
Norton 7x[g]	ϵ'/ϵ_o	9.65	9.64	9.64	9.64	9.64	9.64	9.64	----	----	----	9.63	9.62		
(density = 3.86 gm/cc)	tan δ	15.2	15.5	13.2	9	2.7	1.0	1.5	----	----	----	3.2	2.3		
Norton 17Z[g]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	9.20			
	tan δ	----	----	----	----	----	----	----	----	----	----	0.6			
Raytheon 402B[h]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	9.42			
	tan δ	----	----	----	----	----	----	----	----	----	----	.14			
Stupakoff 1510[i,j]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	5.72			
	tan δ	----	----	----	----	----	----	----	----	----	----	16*			
Stupakoff 1540[i,k]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.97			
	tan δ	----	----	----	----	----	----	----	----	----	----	5.8			
Stupakoff 1542E[i,l]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	9.15			
	tan δ	----	----	----	----	----	----	----	----	----	----	6.8			
Stupakoff 1542P[i,m]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	9.34			
	tan δ	----	----	----	----	----	----	----	----	----	----	5.5			

a. Diamonite. b. Frenchtown. c. Alumina-mulite. d. Gen. Ceramics. e. Kearfott. f. Nat'l Res. Corp. g. Norton, experimental materials.
h. Raytheon. i. Stupakoff. j. 99.8% Al_2O_3, 10% porosity. k. 95% Al_2O_3, vitrified. l. 96% Al_2O_3, extruded. m. 96% Al_2O_3, pressed.
*At 50% relative humidity.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I A 2a. Aluminas (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
Stupakoff 1550[a,b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.72			
	tan δ	----	----	----	----	----	----	----	----	----	----	16			
"Wesgo" AL-300[c,d]	ϵ'/ϵ_o	----	9.6	9.6	9.6	9.6	9.6	----	9.6	----	----	9.63			
	tan δ	----	8	2.5	1	1	0.7	----	1.6	----	----	5.5			
"Wesgo" AL-1009[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.03			
	tan δ	----	----	----	----	----	----	----	----	----	----	3.7			
I A 2b. Ferrites (Detailed data on other ferrites in ferromagnetics section). Values of tan δ are given without multiplying factor.															
Magnesium manganite[e]	ϵ'/ϵ_o	----	2710	869	98.3	24.6	18.4	15.5	----	12.1	11.2	10.9			
	tan δ	----	6.62	2.95	3.90	1.66	0.41	0.18	----	0.081	0.004	0.018			
"Ferramic" H-1[e]	ϵ'/ϵ_o	----	----	----	6940										
	tan δ_d	----	----	----	2.02	----	268	21.4							
	μ'/μ_o	----	680	672	660	570	268	21.4							
	tan δ_m	----	----	----	----	0.06	0.42	3.9							
"Ferroxcube" 105[f]	ϵ'/ϵ_o	----	----	----	----	----	11.9	----	11.2	11.0	11.0				
	tan δ_d	----	----	----	----	----	0.070	----	0.07	0.034	0.014				
	μ'/μ_o	----	----	----	----	----	----	----	----	3.53	0.57				
	tan δ_m	----	----	----	----	----	----	----	----	2.50	6.75				
I A 2c. Steatite	Values of tan δ are multiplied by 10^4; frequency given in c/s.														
Gen. Ceramics BN-3054	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	6.34			
	tan δ	----	----	----	----	----	----	----	----	----	----	18			
I A 2d. Wollastonites															
"AlSiMag" 577[g]	ϵ'/ϵ_o	6.54	6.54	6.54	6.54	6.54	6.54	6.53	6.52	----	----	6.45			
	tan δ	11	7.2	6.0	5.3	3.9	2.7	5.0	7.2	----	----	24			
Rutgers E-16[h]	ϵ'/ϵ_o	----	----	----	----	6.38	----	----	----	----	----	6.35	----	6.34	
(density = 2.85 gm/cc)	tan δ	----	----	----	----	1.9	----	----	----	----	----	12.5	----	17.0	

a. Stupakoff. b. 83% Al_2O_3, balance principally silica and calcium oxides. c. Western Gold and Platinum. d. 97% Al_2O_3, remainder mostly MgO.
e. Gen. Ceramics. f. Ferroxcube. g. Amer. Lava. h. Ceramics School, Rugers University.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
I A 2e. Zircon															
"AlSiMag" 475[a,b]	ϵ'/ϵ_o	9.07	8.66	8.57	8.5	8.5	8.5	8.5	8.5	----	----	8.35	7.51*	7.45*	
(density = 3.69 gm/cc)	tan δ	360	170	50	11	4.2	3.0	4.7	6.6	----	----	27	33	50	
I A 3. Glasses															
Corning 7910	ϵ'/ϵ_o	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	----	----	3.79			
Corning 8603:	tan δ	4.1	4.1	4.0	3.8	3.3	3.0	2.7	2.6	----	----	5.0			
"Fotoform" B (843GU)	ϵ'/ϵ_o	----	6.82	----	----	----	----	----	----	----	----	6.29	6.26	6.20	
	tan δ	----	186	----	----	----	----	----	----	----	----	137	149	195	
"Fotoform" B (843GZ)	ϵ'/ϵ_o	----	7.07	----	----	----	----	----	----	----	----	6.30	6.28	6.24	
	tan δ	----	257	----	----	----	----	----	----	----	----	147	177	246	
"Fotoform" C (843GU)	ϵ'/ϵ_o	----	5.95	----	----	----	----	----	----	----	----	5.64	5.62	5.59	
	tan δ	----	58	----	----	----	----	----	----	----	----	117	134	165	
"Fotoform" C (843GZ)	ϵ'/ϵ_o	----	6.01	----	----	----	----	----	----	----	----	5.71	5.70	5.69	
	tan δ	----	73	----	----	----	----	----	----	----	----	133	158	173	
"Fotoform" E (843GU)	ϵ'/ϵ_o	----	6.03	----	----	----	----	----	----	----	----	5.68	5.67	5.65	
	tan δ	----	43	----	----	----	----	----	----	----	----	104	139	160	
"Fotoform" E (843GZ)	ϵ'/ϵ_o	----	6.05	----	----	----	----	----	----	----	----	5.75	5.74	5.73	
	tan δ	----	73	----	----	----	----	----	----	----	----	123	160	168	
"Fotoceram" (843GU)	ϵ'/ϵ_o	----	5.62	----	----	----	----	----	----	----	----	5.45	5.44	5.43	
	tan δ	----	71	----	----	----	----	----	----	----	----	82	94	103	
"Fotoceram" (843GZ)	ϵ'/ϵ_o	----	5.63	----	----	----	----	----	----	----	----	5.46	5.45	5.44	
	tan δ	----	50	----	----	----	----	----	----	----	----	94	106	129	
"Ceram" 61-1[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	5.39		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	4.5		
"Ceram" 61-2[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	5.38		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	4.0		
"Ceram" 61-3[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	6.16		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	4.0		

a. Amer. Lava. b. Zircon porcelain. c. Corning.
*Density = 3.43 gm./cc.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I A 3. Glasses (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Ceram" 61-4[a]	ϵ'/ϵ_o	-----	----	----	----	----	----	----	----	----	----	----	6.14		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	2.0		
"Ceram" 61-5[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	5.85		
	tan δ	----	----	----	----	----	----	----	----	----	----	----	2.5		
Owens-Corning CR-262[b]	ϵ'/ϵ_o	7.14	7.05	7.00	6.95	6.95	6.94	6.88	6.84	----	----	6.79			
	tan δ	95	70	55	46	42	40	47	55	----	----	130			
Owens-Corning 57M[b]	ϵ'/ϵ_o	6.52	6.50	6.50	6.48	6.50	6.49	6.46	6.44	----	----	6.42			
	tan δ	21	19	18	16	17	19	25	28	----	----	52			
Ownes-Corning EA63[b]	ϵ'/ϵ_o	7.26	7.16	7.12	7.10	7.09	7.06	7.00	6.98	----	----	6.92			
	tan δ	115	78	59	50	44	45	51	64	----	----	140			
Owens-Corning EA73[b]	ϵ'/ϵ_o	6.64	6.60	6.59	6.57	6.56	6.56	6.55	6.53	----	----	6.51			
	tan δ	30	21	18	15	14	18	23	28	----	----	57			
Owens-Corning X600[b]	ϵ'/ϵ_o	4.07	4.07	4.07	4.06	4.06	4.06	4.06	4.05	----	----	4.02			
	tan δ	7.4	5.8	4.0	4.0	4.8	6.8	9.3	11	----	----	17			
Fused Quartz, Clear[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	3.79			
	tan δ	----	----	----	----	----	----	----	----	----	----	1.1			
Fused Quartz, Translucent[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	3.65			
	tan δ	----	----	----	----	----	----	----	----	----	----	2.6			
I A 4. Miscellaneous Inorganics															
Boron nitride (dried, field ‖	ϵ'/ϵ_o	4.15	4.15	4.15	4.15	4.15	4.15	4.15	----	4.80*	4.80*	4.80*			
to direction of pressing)[d]	tan δ	----	----	----	----	----	----	----	----	0.57*	1.6*	3.1*			
"Fiberfrax" Board[d,e]	ϵ'/ϵ_o	4.81	2.45	1.91	1.75	1.67	1.64	1.62	1.60	1.74	1.64	1.61	1.6		
	tan δ	6500	4100	1180	400	170	140	170	250	460	470	250	360		
Silicon nitride (75%)	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	----	5.02*		
Boron nitride (25%)[d]	tan δ	----	----	----	----	----	----	----	----	----	----	----	300*		

a. Corning b. Research samples (Owens-Corning Fiberglas). c. Syncor. d. Hot-pressed (Carborundum). e. Aluminum-silicate ceramic fibers.

*Electric field ⊥ to direction of pressing.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I A 4. Miscellaneous Inorganics (cont.)

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Eccofoam" HiK (1000°F)-2.5[a]	ϵ'/ϵ_o	----	2.62	----	----	----	----	----	----	----	----	2.49			
	$\tan\delta_d$	----	175	----	----	----	----	----	----	----	----	49			
	μ'/μ_o	----	----	----	----	----	----	----	----	----	----	0.992			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	45			
"Eccofoam" HiK (1000°F)-3[a]	ϵ'/ϵ_o	----	3.02	----	----	----	----	----	----	----	----	3.08			
	$\tan\delta_d$	----	130	----	----	----	----	----	----	----	----	53			
	μ'/μ_o	----	----	----	----	----	----	----	----	----	----	0.960			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	52			
"Eccofoam" HiK (1000°F)-5[a]	ϵ'/ϵ_o	----	5.48	----	----	----	----	----	----	----	----	5.35			
	$\tan\delta_d$	----	143	----	----	----	----	----	----	----	----	75			
	μ'/μ_o	----	----	----	----	----	----	----	----	----	----	0.961			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	101			
Pipestone (50% R.H.)[b]	ϵ'/ϵ_o	40	13.9	8.93	6.86										
	tan δ	8400	2000	725	160										
Pipestone (baked, then	ϵ'/ϵ_o	5.15	5.10	5.07											
paraffin impregnated)[b,c]	tan δ	46	32	28											
"Supramica" 500[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	6.94			
(density 3.04 gm/cc)	tan δ	----	----	----	----	----	----	----	----	----	----	24			
Sauereisen Cement No. 1	ϵ'/ϵ_o	270	70	21	10.5	6.8	5.5	4.8							
(after wet grinding)	tan δ	86500	38600	19300	7800	2900	1100	620							
Sauereisen Cement No. 1	ϵ'/ϵ_o	4.55	3.80	3.55	3.49	3.46	3.44	3.43	----	3.43	3.43				
(after drying at 200°C)	tan δ	3900	1300	400	190	82	60	56	----	54	54				
"Mica-ramic"	ϵ'/ϵ_o	4.55	3.97	3.76	3.71	3.69	3.69	3.68							
(as received)[e]	tan δ	1240	590	210	78	23	17	22							
"Mica-ramic"	ϵ'/ϵ_o	3.70	3.68	3.67	3.67	3.67	3.67	3.67							
(after drying)[e]	tan δ	69	46	33	23	17	15	15							

a. Emerson and Cuming. b. Hunson. c. Paraffin treated (Lab. Ins. Res.). d. Mycalex. e. Spruce Pine Mica.

I B. Solids, organic

1. Plastics (including plastics with fillers, laminates).

Values of tan δ are multiplied by 10^4; frequency given in c/s.

a. Phenolics		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
Phenolic impregnated	ϵ'/ϵ_o	4.17	4.12	4.06	3.95	3.80	3.66	3.52	----	3.50	----	3.43			
"Dacron" batt[a]	tan δ	103	100	157	231	270	271	-275	----	312	----	360			
Phenolic impregnated	ϵ'/ϵ_o	3.75	3.72	3.69	3.61	3.51	3.40	3.32	----	3.29	3.28	33.27			
woven "Dacron" fabric[a]	tan δ	59	66	114	167	190	202	240	----	280	280	230			
Phenolic impregnated	ϵ'/ϵ_o	7.42	6.03	5.25	4.73	4.21	3.85	3.61	----	3.50	----	3.32			
"Nylon" batt[a]	tan δ	1760	1060	922	900	708	517	440	----	364	----	377			
Phenolic impregnated	ϵ'/ϵ_o	3.99	3.88	3.78	3.68	3.56	3.45	3.35	3.30	3.24	3.20	3.13			
woven "Nylon" fabric[a]	tan δ	192	161	290	235	208	186	199	206	215	223	234			
Phenolic impregnated	ϵ'/ϵ_o	4.75	4.54	4.35	4.18	4.05	3.90	3.74	----	3.62	----	3.47			
"Orlon" batt[a]	tan δ	346	295	270	261	245	248	310	----	341	----	384			
Phenolic impregnated	ϵ'/ϵ_o	4.74	4.49	4.30	4.15	4.00	3.85	3.70	3.63	3.54	3.49	3.44			
woven "Orlon" fabric[a]	tan δ	440	325	264	243	218	212	244	245	257	268	327			
"Eccofoam" GL[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	1.41			
	tan δ	----	----	----	----	----	----	----	----	----	----	115			
Phenolic-asbestos laminate,	ϵ'/ϵ_o	25.3	17.1	10.5	6.64	5.11	4.72	4.60	4.5	4.74*	----	4.57*	4.51*	4.47*	
pressed (dried)[c]	tan δ	2350	2880	3340	2610	1070	390	175	194	410*	----	390*	403*	435*	
Phenolic-"fiberglas" laminate	ϵ'/ϵ_o	4.66	4.64	4.60	4.56	4.51	4.44	4.34	4.3	4.78*	4.76*	4.75*	4.74*	4.73*	
laminate pressed (dried)[d]	tan δ	35	39	56	69	72	86	111	151	160*	190*	250*	280*	330*	
Phenolic-"fiberglas"	ϵ'/ϵ_o	4.01	3.98	3.95	3.91	3.87	3.84	3.78	3.7	----	----	4.23*	4.23*	4.22*	
laminate bagged (dried)[e]	tan δ	37	43	47	42	47	72	99	164	----	----	230*	215*	230*	

I B 1 b. Melamine-formaldehyde

"Dilecto" (Melamine glass	ϵ'/ϵ_o	4.69	4.62	4.60	4.59	4.59	4.57	4.52	----	3.98	3.95	3.91			
laminate) GM-1, (dried)[f]	tan δ	46	46	44	49	49	66	98	130	139	143	140			

a. du Pont Textile Fibers Dept. b. Emerson and Cuming. c. "Pyrotex 9526D2, 8 oz. mat (Raybestos Manhatten) with 34% Conolon 506 resin (Narmco) molded at 290°F, 200 psi and cured at temperatures to 400°F (Goodyear). d. 181-14 "Fiberglas" cloth with 31% resin as in (c), molded at 310°F, cured at 350°F (Goodyear). e. Composition same as (d) but with 3-ply bleeder. f. 50% Amer. Cyanamid 405 resin, 50% Owens-Corning T-36 glass mat (Continental Diamond).

*Sample not dried.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 c. Cellulose derivatives		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Forticel" JLB-(H)[a]	ϵ'/ϵ_o	3.59	3.57	3.51	3.41	3.29	3.18	3.08	----	2.97	2.93	2.89			
	tan δ	61	99	159	196	194	180	205	----	264	294	334			
"Forticel" JMB-(M)[a]	ϵ'/ϵ_o	3.94	3.89	3.82	3.70	3.55	3.41	3.25	----	3.06	2.97	2.88			
	tan δ	68	109	182	240	251	260	319	----	392	434	389			
"CTA"[b]	ϵ'/ϵ_o	4.11	3.99	3.86	3.67	3.51	3.38	3.23	----	3.07	3.01	2.92			
	tan δ	140	206	277	306	306	281	218	----	191	206	226			
I B 1 d. Silicon resins															
Silicone Alloy C-1147[c]	ϵ'/ϵ_o	----	----	----	----	2.52	2.52	2.52	2.52	2.51	2.50	2.49	2.48	2.48	2.48
	tan δ	----	----	----	----	0.6	2.5	3.3	4.0	5.0	6.0	7.1	8.1	9.0	14.2
Silicone Alloy C-1328[c]	ϵ'/ϵ_o	----	----	----	----	2.50	2.50	2.50	2.49	2.49	2.48	2.48	2.48	2.48	2.48
	tan δ	----	----	----	----	1.2	3.4	2.2	1.9	2.8	3.2	4.0	4.4	4.8	5.9
DC 301 molding compound[d]	ϵ'/ϵ_o	4.16	4.12	4.10	4.08	4.07	4.06	4.04							
	tan δ	63	63	53	49	50	51	67							
DC 2105 laminate[e]	ϵ'/ϵ_o	3.98	3.98	3.97	3.96	3.96	3.96	3.96	----	4.18	4.17	4.16			
	tan δ	19.3	18.6	15.9	15	14.4	16.6	25	----	58	61	69			
DC 2106 laminate[f]	ϵ'/ϵ_o	4.24	4.24	4.22	4.22	4.21	4.21	4.21	----	4.32	4.31	4.30			
	tan δ	23	18.2	15.2	12	14	17	23	----	45	52	66			
Silicone - asbestos	ϵ'/ϵ_o	12.80	9.90	6.65	4.59	3.68	3.45	3.39	3.3	3.68*	3.58*	3.52*	3.49*	3.49*	
laminate[g]	tan δ	1870	2400	2650	2090	1020	460	50	45	500*	340*	210*	190*	130*	
Silicone - "fiberglas" laminate,	ϵ'/ϵ_o	3.66	3.63	3.61	3.60	3.59	3.58	3.56	3.5	3.91*	3.88*	3.85*	3.83*	3.81*	
pressed (dried)[h]	tan δ	10.7	9.8	8.7	9.4	10.0	12.2	19	26	33*	43*	65*	75*	113*	
Silicone - "fiberglas" laminate,	ϵ'/ϵ_o	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.1	----	3.84*	3.80*	3.78*	3.75*	
bagged (dried)[i]	tan δ	21.3	16.7	15.4	14	13.2	13.1	19.3	24	----	56*	70*	88*	110*	

a. Cellulose propionate (Celanese). b. Cellulose tri-acetate (du Pont Film Dept.). c. Delaware Res. Dev. d. 45% chopped glass fibers, 20% silica, 35% polysiloxane resin (Dow-Corning). e. 50% EC-116 glass fabric, 50% polysiloxane resin (Dow-Corning). f. 70% ECC-181 glass fabric, 30% polysiloxane resin (Dow-Corning). g. 50% "Pyrotex" felt 9526DB-5, impregnated with 50% DC-2106 resin (U.S. Polymeric), molded at 350°F, 300 psi, and cured at temperatures to 470°F (Goodyear). h. 65% 181-112 cloth, 35% DC-2106 resin molded at 315°F, cured at temperatures to 480°F (Goodyear).
i. Composition same as (a), but with 3-ply bleeder, 33% resin.

*Not dried.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 e. Polyvinyl resins

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
(1). Polyethylenes															
"Fortiflex" A[a]	ϵ'/ϵ_o	2.39	2.38	2.38	2.38	2.38	2.38	2.38	----	2.38	2.38	2.37			
	tan δ	1.1	0.37	0.25	<0.5	<0.3	<0.3	0.3	----	3.1	2.6	1.9			
"Marlex" 50[b]	ϵ'/ϵ_o	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.39	2.39	2.38	2.38	2.38	
	tan δ	1.6	0.33	0.28	<0.5	0.28	<0.3	0.32	0.9	2.4	2.15	1.6	1.9	2.1	
(2). Polyvinyl chloride-acetate															
"Boltaron" 6200-10[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.81					
	tan δ	----	----	----	----	----	----	----	----	82					
(3). Polychlorotrifluoroethylene															
"KEL-F" X200[d]	ϵ'/ϵ_o	3.13	3.00	2.84	2.70	2.56	2.45	2.36	----	2.30	2.28	2.27			
	tan δ	198	292	398	420	320	220	180	----	96	73	56			
(4). Polytetrafluoroethylene															
"Teflon" (77%) plus	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.38					
calcium fluoride (23%)[e]	tan δ	----	----	----	----	----	----	----	----	57					
(5). Polyacrylates															
"Lucite" Type HC-202[f]	ϵ'/ϵ_o	3.27	3.01	2.87	2.76	2.71	2.66	2.63	----	2.58	2.56	2.55			
	tan δ	590	446	300	202	142	90	63	----	43	37	33			
Acrylic impregnated	ϵ'/ϵ_o	3.76	3.47	3.25	3.10	2.98	2.91	2.84	----	2.77	2.74	2.72			
Orlon batt[g]	tan δ	664	503	362	277	213	168	118	----	86	72	59			
(6). Polystyrene															
Polystyrene impregnated	ϵ'/ϵ_o	3.11	3.10	3.10	3.10	3.10	3.10	3.10	---	3.16	3.16	3.16			
"Fiberglas"[g]	tan δ	55	24.6	18.2	15.6	4.6	6.1	11.3	----	28	39	36			
Polystyrene impregnated	ϵ'/ϵ_o	3.02	3.01	3.00	3.00	3.00	2.97	2.91	----	2.87	2.84	2.82			
"Dacron" batt[g]	tan δ	43	30	32.6	46	60	79	78	----	113	130	157			
Polystyrene impregnated	ϵ'/ϵ_o	3.09	2.98	2.92	2.89	2.87	2.86	2.85	----	2.89	2.88	2.87			
"Orlon" batt[g]	tan δ	211	159	113	78	45	33	26	----	26	28	36			
"Eccofoam" PS (K=1.2)[h]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	1.182			
	tan δ	----	----	----	----	----	----	----	----	----	----	1.2			

a. Linear polyethylene (Celanese). b. Low pressure, hi-density polyethylene (Phillips). c. 100% unplasticized polyvinyl chloride (Hartwell). d. Kellogg. e. Ethylene Chem. f. Methyl methacrylate (du Pont Polychemicals). g. du Pont Textile Fibers Dept. h. Samples also measured having ϵ'/ϵ_o = 1.362, tan δ = 0.00032; and ϵ'/ϵ_o = 2.05, tan δ = 0.00165 (Emerson & Cuming).

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 e. Polystyrene (cont.)

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
(7). Miscellaneous polystyrenes															
Polytrifluorostyrene (film)[a]	ϵ'/ϵ_o	2.56	2.56	2.56	2.56	2.56	2.56	2.56	----	----	----	2.54			
	tan δ	34	27	16.5	14	6.2	6.3	6.9	----	----	----	19			
Polycyclostyrene[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	2.51	2.49			
	tan δ	----	----	----	----	----	----	----	----	----	--31	26			
(8). Styrene copolymers, cross linked															
"Pelron" 9420[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.59	2.54				
	tan δ	----	----	----	----	----	----	----	----	22	29				
"Pelron" 9422[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.61	2.61				
	tan δ	----	----	----	----	----	----	----	----	44	51				
"Pelron" 9423[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.62	2.61				
	tan δ	----	----	----	----	----	----	----	----	50	59				
"Pelron" 9424[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.60	2.60				
	tan δ	----	----	----	----	----	----	----	----	30	39				
"Ecco" L65[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	2.58	2.58				
	tan δ	----	----	----	----	----	----	----	----	30	34				
"Stycast" LoK[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----			1.68			
	tan δ	----	----	----	----	----	----	----	----	----	----	26			
"Stycast" HiK (K=7)[d,e]	ϵ'/ϵ_o	7.25	7.15	7.08	7.06	----	7.03	----	----	----	----	6.85			
	tan δ	99	61	36	23	----	9.5	----	----	----	----	11			
"Stycast" TPM-3[d]	ϵ'/ϵ_o	2.40	2.40	2.40	2.40	2.39	2.37	2.36	----	----	----	2.35			
	tan δ	2.9	1.7	1.9	2.8	7.3	7.2	5.8	----	----	----	4.6			
"Rexolite" 2101[h]	ϵ'/ϵ_o	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.72	----	----	2.75			
	tan δ	13.5	9.6	7.5	5	4	6.5	10	12	----	----	19			
I B 1 f. Polyesters															
"Atlac" 382 (70%)-styrene	ϵ'/ϵ_o	3.08	3.05	3.02	3.00	2.96	2.92	2.87	----	2.82	2.78	2.72			
(30%)[i]	tan δ	85	75	70	80	110	132	142	----	135	120	105			

a. Polaroid. b. Monsanto, Ohio. c. East Coast Aeronautics. d. Emerson and Cuming. e. Manufactured with K=3 to 15. h. "Fiberglas" laminate (Rex). i. Atlas Powder.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 f. Polyesters (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Atlac" 382 (50%) - styrene	ϵ'/ϵ_o	2.91	2.90	2.89	2.87	2.84	2.82	2.77	----	2.72	2.69	2.65			
(50%)[a]	tan δ	42	44	44	54	73	90	115	----	108	95	75			
"Bakelite" PLLA-5005[b]	ϵ'/ϵ_o	2.22	2.05	1.97	1.90	1.84	1.78	1.73	----	1.69	1.67	1.65			
	tan δ	1006	396	255	218	200	210	240	----	235	200	200			
"Dilecto" (glass mat polyester)	ϵ'/ϵ_o	4.65	4.57	4.53	4.50	4.45	4.43	4.40	----	4.40	4.35	4.30			
GM-PE (dried)[c]	tan δ	48	45	41	63	77	96	120	----	95	102	106			
Celanese MR-31C	ϵ'/ϵ_o	3.43	3.40	3.36	3.32	3.26	3.17	3.11	----	2.97	2.93	2.86			
	tan δ	65	61	78	125	148	143	160	----	147	124	114			
Celanese MR-33C	ϵ'/ϵ_o	3.11	3.06	3.06	3.02	2.98	2.97	2.94	----	2.91	2.89	2.82			
	tan δ	22	27	46	79	82	87	128	----	145	130	129			
Celanese MX-186	ϵ'/ϵ_o	5.55	5.26	4.98	4.70	4.42	4.15	3.86	----	3.55	3.42	3.28			
	tan δ	360	360	370	370	370	500	600	----	570	470	380			
Celanese MX-218	ϵ'/ϵ_o	3.91	3.81	3.71	3.63	3.56	3.47	3.33	----	----	----	----	2.96	2.94	
	tan δ	202	172	162	162	161	195	320	----	----	----	----	410	288	
Polyester impregnated	ϵ'/ϵ_o	3.37	3.35	3.32	3.28	3.20	3.13	3.05	3.03	3.00	2.99	2.98			
"Dacron" batt[d]	tan δ	48	51	86	152	182	179	143	123	98	81	68			
Polyester impregnated	ϵ'/ϵ_o	3.61	3.53	3.47	3.37	3.26	3.15	3.07	----	3.03	3.02	3.01			
"Dacron" batt[e]	tan δ	119	111	135	185	226	223	205	----	144	105	113			
Polyester impregnated	ϵ'/ϵ_o	2.99	2.96	2.89	2.86	2.83	2.77	2.71	----	2.74	----	2.65			
woven "Dacron" fabric[d]	tan δ	39	47	80	127	152	152	137	----	92	----	93			
Polyester impregnated	ϵ'/ϵ_o	3.84	3.72	3.59	3.45	3.32	3.22	3.09	3.05	3.00	2.96	2.91			
"Nylon" batt[d]	tan δ	309	239	255	283	261	185	137	126	113	105	97			
Polyester impregnated	ϵ'/ϵ_o	3.16	3.12	3.04	2.93	2.86	2.77	2.54	----	2.92	----	2.89			
woven "Nylon" fabric[d]	tan δ	133	146	196	233	228	197	167	----	84	----	76			
Polyester impregnated	ϵ'/ϵ_o	3.72	3.61	3.50	3.40	3.31	3.24	3.18	3.15	3.13	3.11	3.08			
"Orlon" batt[d]	tan δ	277	200	184	187	186	170	139	120	100	92	89			
Polyester impregnated	ϵ'/ϵ_o	4.08	3.90	3.78	3.68	3.60	3.51	3.39							
woven "Orlon" fabric[d]	tan δ	337	258	201	179	160	141	125							

a. Atlas Powder. b. Phenolic spheres in polyester resin (Bakelite). c. Continental Diamond. d. Rohm and Haas', "Paraplex" P-43 resin (du Pont Textile Fibers Dept.) e. Robertson's "Stypol" 16D resin (du Pont Textile Fibers Dept.).

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 f. Polyesters (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Mylar" A[a] electric field	ϵ'/ϵ_o	3.17	3.15	3.13	3.07	2.99	2.92	2.87	----	2.81	2.79	3.19*			
to film	tan δ	19.1	41.0	89.9	145	166	160	130	----	76	61	44*			
"Cronar"[b]	ϵ'/ϵ_o	3.37	3.36	3.33	3.29	3.23	3.17	3.10	----	3.01	2.96	2.90			
	tan δ	15	36	84	140	175	170	150	----	120	105	82			
"Eccosorb" HF155[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	17.8			
	tan δ	----	----	----	----	----	----	----	----	----	----	3700			
"Eccosorb" HF680[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	23.2			
	tan δ	----	----	----	----	----	----	----	----	----	----	2700			
"Eccosorb" HF853[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	19.5			
	tan δ	----	----	----	----	----	----	----	----	----	----	2700			
"Eccosorb" HF1000[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	12.8			
	tan δ	----	----	----	----	----	----	----	----	----	----	1600			
"Eccosorb" HF2050[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	9.1			
	tan δ	----	----	----	----	----	----	----	----	----	----	1500			
"Eccosorb" HFX122[c,d]	ϵ'/ϵ_o	----	----	23,000	23,000	6200	1070	----	----	----	----	42			
	tan δ	----	----	330*	33*	12*	7*	----	----	----	----	5300			
"Eccosorb" HFX123[c,e]	ϵ'/ϵ_o	----	----	20,400	16,000	2400	1070	----	----	----	----	22			
	tan δ	----	----	304*	38*	24*	5.8*	----	----	----	----	8900			
Hooker 32A, "Fiberglas"	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	3.70	3.68	3.67			
cloth laminate[f]	tan δ	----	----	----	----	----	----	----	----	135	141	128			
Hooker 32A, "Fiberglas"	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	3.68	3.63	3.62			
mat[g]	tan δ	----	----	----	----	----	----	----	----	141	148	168			
Hooker 32A, "Fiberglas"	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	3.78	3.75	3.73			
mat with fire retardent[h]	tan δ	----	----	----	----	----	----	----	----	118	143	143			
"Selectron" 5084[i]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	2.89			
	tan δ	----	----	----	----	----	----	----	----	----	----	155			

a. du Pont Film Dept. b. du Pont Photo Products Dept. c. Emerson and Cuming. d. 43.6% Graphite, 56.4% resin. e. 16.2% Acetylene black, 83.8% resin. f. Chlorinated polyester resin, 2% ATC catalyst, with 50% Owens-Corning 181 Volan cloth (Hooker). g. Same resin with 45% Owens-Corning OCF T219 glass mat (Hooker). h. Same as g but with 5% Sb_2O_3 added to resin (Hooker). i. Pittsburg Corning.

*Electric field ||. **tan δ not multiplied by 10^4.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 g. Epoxy resins		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Dilecto" (Epoxy-glass laminate)	ϵ'/ϵ_o	5.20	5.16	5.10	4.99	4.90	4.76	4.66	4.82	4.75	4.67	4.64			
GB-116E[a]	tan δ	46	72	118	176	185	205	233	162	170	176	213			
"Dilecto" (Epoxy-glass laminate)	ϵ'/ϵ_o	5.25	5.21	5.12	5.00	4.91	4.75	4.63	4.65	4.54	4.48	4.42			
GB-126E[a]	tan δ	60	74	136	190	192	202	223	175	186	182	210			
"Dilecto" (Epoxy-glass laminate)	ϵ'/ϵ_o	5.25	5.21	5.14	5.03	4.90	4.77	4.65	4.85	4.80	4.73	4.64			
GB-181E[a]	tan δ	42	67	131	178	204	226	268	165	179	202	218			
Epoxy impregnated	ϵ'/ϵ_o	4.12	4.08	4.00	4.84	3.66	3.49	3.37	----	3.25	3.21	3.16			
"Dacron" batt[b]	tan δ	49	107	208	277	290	300	300	----	270	260	240			
Epoxy impregnated	ϵ'/ϵ_o	3.71	3.69	3.66	3.59	3.49	3.39	3.30	----	3.18	3.15	3.12			
woven "Dacron" fabric[b]	tan δ	32	51	102	158	194	248	256	----	310	300	250			
Epoxy impregnated	ϵ'/ϵ_o	4.62	4.48	4.28	4.03	3.78	3.64	3.45	----	3.24	----	3.06			
"Nylon" batt[b]	tan δ	189	253	369	407	336	323	330	----	320	----	280			
Epoxy impregnated	ϵ'/ϵ_o	4.34	4.26	4.11	3.91	3.72	3.61	3.53	----	3.33	3.25	3.12			
woven "Nylon" fabric[b]	tan δ	125	183	285	334	304	314	343	----	320	310	270			
Epoxy impregnated	ϵ'/ϵ_o	4.42	4.23	4.07	3.93	3.81	3.69	3.54	----	3.32	----	3.15			
"Orlon" batt[b]	tan δ	332	284	257	235	203	233	268	----	204	----	181			
Epoxy impregnated	ϵ'/ϵ_o	4.35	4.18	4.02	3.89	3.76	3.68	3.57	----	3.45	3.38	3.32			
woven "Orlon" fabric[b]	tan δ	304	251	236	229	215	237	310	----	310	300	280			
"Eccofoam" HiK (500°F)	$\epsilon'/\epsilon_o \cdot \mu'/\mu_o$	----	----	----	----	----	----	----	----	----	----	2.41			
(K = 2.4)[c]	$\tan\delta_d + \tan\delta_m$	----	----	----	----	----	----	----	----	----	----	160			
"Eccofoam" HiK (500°F)	$\epsilon'/\epsilon_o \cdot \mu'/\mu_o$	----	----	----	----	----	----	----	----	----	----	4.53			
(K = 4.5)[c]	$\tan\delta_d + \tan\delta_m$	----	----	----	----	----	----	----	----	----	----	270			
"Eccofoam" HiK (500°F)	$\epsilon'/\epsilon_o \cdot \mu'/\mu_o$		----	----	----	----	----	----	----	----	----	5.85			
(K = 5.9)[c]	$\tan\delta_d + \tan\delta_m$		----	----	----	----	----	----	----	----	----	460			
"Eccofoam" HiK (500°F)	$\epsilon'/\epsilon_o \cdot \mu'/\mu_o$	----	----	----	----	----	----	----	----	----	----	7.54			
(K = 7.5)[c]	$\tan\delta + \tan\delta_m$	----	----	----	----	----	----	----	----	----	----	460			

a. Continental Diamond. b. du Pont Textile Fibers Dept. c. Emerson and Cuming.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1g. Epoxy resins (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Eccosorb" MF110[a]	ϵ'/ϵ_o	----	----	5.38	5.18	----	----	----	----	----	----	3.95			
	$\tan\delta_d$	----	----	161	234	----	----	----	----	----	----	326			
	μ'/μ_o	----	----	1.33	1.33	----	----	----	----	----	----	1.115			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	880			
"Eccosorb" MF112[a]	ϵ'/ϵ_o	----	----	6.72	6.55	----	----	----	----	----	----	5.00			
	$\tan\delta_d$	----	----	162	247	----	----	----	----	----	----	334			
	μ'/μ_o	----	----	1.67	1.67	----	----	----	----	----	----	1.40			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	1890			
"Eccosorb" MF114[a]	ϵ'/ϵ_o	----	----	11.2	10.8	----	----	----	----	----	----	8.60			
	$\tan\delta_d$	----	----	181	255	----	----	----	----	----	----	338			
	μ'/μ_o	----	----	2.64	2.64	----	----	----	----	----	----	1.66			
	$\tan\delta_m$	----	----	----	----	----	----	----	----	----	----	3900			
"Eccosorb" MF116[a,b]	ϵ'/ϵ_o	19.9	19.6	19.2	18.5	18.1	17.1	16.9	----	----	----	13.6			
	$\tan\delta_d$	134	128	177	228	254	307	394	----	----	----	220			
	μ'/μ_o	4.22	4.22	4.22	4.22	4.22	4.22	4.20	3.90	3.75	2.34	1.12			
	$\tan\delta_m$	----	----	----	----	<100	<100	<200	570	2650	4820	6000			
"Eccosorb" MF117[a,c]	ϵ'/ϵ_o	24.2	23.9	23.2	----	21.4	19.9	19.6	----	----	----	17.2			
	$\tan\delta_d$	94	144	250	----	360	390	420	----	----	----	380			
	μ'/μ_o	4.85	4.85	4.85	4.85	4.85	4.85	4.80	4.69	4.31	2.57	1.96			
	$\tan\delta_m$	----	----	----	----	<100	<50	<200	560	2950	5600	7300			
"Hysol" 6000 HD[d]	ϵ'/ϵ_o	3.22	3.21	3.19	3.15	3.10	3.01	2.90	----	2.84	2.82	2.81			
	$\tan\delta$	34	44	74	108	133	146	180	----	132	120	116			
"Hysol" 6030-B[d]	ϵ'/ϵ_o	9.7	9.4	8.9	8.1	7.3	5.8	4.3	----	3.30	3.27	----			
	$\tan\delta$	5600	1160	670	540	1000	2300	1100	----	635	660	-----			
"Hysol" XL-6060[d]	ϵ'/ϵ_o	8.80	7.56	6.45	5.60	4.90	4.35	3.70	----	3.40	3.23	3.10			
	$\tan\delta$	2500	1450	1040	840	960	1140	1150	----	670	570	370			

a. Emerson and Cuming. b. 81.2% Carbonyl iron, 18.8% resin. c. 85.8% Carbonyl iron, 14.2% resin. d. Houghton Labs.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 1 g. Epoxy resins (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Hysol" XE-6080[a]	ϵ'/ϵ_o	3.70	3.55	3.42	3.34	3.28	3.20	3.06	----	2.86	2.83	2.81			
	tan δ	77	69	80	126	194	280	270	----	215	194	195			
"Scotchply" type 1001[b]	ϵ'/ϵ_o	6.60	5.98	5.59	5.32	5.10	4.89	4.71	----	4.59	4.48	4.38			
(molded, uncured)	tan δ	571	458	342	207	219	288	384	----	450	470	460			
"Scotchply" type 1001[b]	ϵ'/ϵ_o	5.18	5.12	5.02	4.92	4.82	4.68	4.57	----	4.56	4.56	4.56			
(cured)	tan δ	78	97	139	166	184	199	194	----	178	168	152			
"Epon" 828-curing agent CL[c]	ϵ'/ϵ_o	4.56	4.48	4.34	4.12	3.91	3.72	3.55	----	3.29	3.23	3.23			
	tan δ	61	150	290	370	340	340	360	----	310	310	330			
"Epon" 828-curing agent D[c]	ϵ'/ϵ_o	3.58	3.55	3.52	3.47	3.36	3.27	3.18	----	3.03					
	tan δ	27	45	88	170	230	270	240	----	250					
"Epon" 828-curing agent	ϵ'/ϵ_o	3.61	3.61	3.59	3.56	3.47	3.38	3.27	----	2.94					
piperidine[c]	tan δ	18	23	56	130	180	220	260	----	270					
"Epon" 828-curing agent	ϵ'/ϵ_o	3.84	3.84	3.79	3.68	3.51	3.37	3.30	3.14	3.05	3.00	2.97	2.94	2.93	
BF_3-400[c]	tan δ	44	64	135	257	312	305	280	250	222	202	203	210	186	
"Epon" 828 "fiberglas" laminate,	ϵ'/ϵ_o	4.82	4.79	4.74	4.68	4.60	4.47	4.32	----	4.34	4.28	4.25	4.22	4.21	
curing agent BF_3-400[c,d]	tan δ	46	41	69	124	171	182	168	----	135	131	131	148	192	
"Epon" X131 "fiberglas"	ϵ'/ϵ_o	5.46	5.42	5.38	5.27	5.24	5.06	4.84	----						
laminate, No. 51[c]	tan δ	39	40	62	124	184	246	304							
I B 1 h. Miscellaneous plastics															
"Penton"[e]	ϵ'/ϵ_o	3.03	2.99	2.95	2.92	2.88	2.85	2.81	----	2.73	2.70	2.63			
	tan δ	112	98	85	79	98	124	170	----	196	155	112			
"Policap"[f]	ϵ'/ϵ_o	4.12	3.80	3.40	3.05	2.88	2.82	2.80	----	2.75	2.75	2.75			
	tan δ	444	666	748	513	233	107	71.5	----	62.0	60	52			
I B 2. Waxes															
Morse 200	ϵ'/ϵ_o	2.34	2.34	2.34	2.34	2.34	2.3								
	tan δ	9.1	7.6	7.0	5.9	10	10								

a. Houghton Labs. b. "Fiberglas" laminate (Minn. Mining). c. Shell. d. 181-"Volan" A cloth pressed at 125°C, cured at 330°F, 200 psi, post-cured 4 hours at 200°C; resin content 23.8%. e. Chlorinated polyether (Hercules). f. Lovell.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
I B 2. Waxes (cont.)															
Morse 280	ϵ'/ϵ_o	3.30	3.03	2.71	2.53	2.48	2.48								
	tan δ	620	690	660	290	66	29								
Morse 300	ϵ'/ϵ_o	3.74	3.07	2.71	2.64	2.61	2.60								
	tan δ	1810	1030	490	189	83	46								
Morse 400	ϵ'/ϵ_o	2.88	2.74	2.68	2.62	2.58	2.52								
	tan δ	474	267	136	103	152	87								
Morse 6060-C	ϵ'/ϵ_o	2.18	2.17	2.15	2.14	2.11	2.11								
	tan δ	52	56	41	20	7	3								
Morse 6062	ϵ'/ϵ_o	2.31	2.31	2.31	2.31	2.28	2.25								
	tan δ	13.5	10	11	10	11	9								
I B 3. Miscellaneous organics															
"Missileon"[a]	ϵ'/ϵ_o	6.00	5.14	4.69	4.43	4.25	4.08	3.98	----	----	----	3.88			
	tan δ	1410	870	500	330	280	260	260	----	----	----	560			
"Rocketon"[a]	ϵ'/ϵ_o	7.66	5.88	5.02	4.58	4.29	4.11	3.99	----	----	----	3.95			
	tan δ	2280	1500	860	540	360	320	350	----	----	----	440			
"Rocketon" (Modification 30)[a]	ϵ'/ϵ_o	4.46	4.13	3.97	3.86	3.80	3.73	3.68	----	----	----	3.59			
	tan δ	774	430	223	163	125	124	142	----	----	----	220			
Irvington varnished linen tape	ϵ'/ϵ_o	----	----	----	4.22	----	2.58								
	tan δ	----	----	----	513	----	560								
"Scotch" tape No. 39[b]	ϵ'/ϵ_o	----	----	----	----	----	3.34 (at $3x10^7$)								
	tan δ	----	----	----	----	----	390 (at $3x10^7$)								
Sealing Compound EC-612[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	17.4				
	tan δ	----	----	----	----	-----	----	----	----	----	1140				
"Ferrotron" 119 (core)[c]	ϵ'/ϵ_o	31.8	29.1	27.9	27.2	26.8	26.3	25.2	----	24	24	24	20		
	tan δ_d	1130	460	230	160	130	144	150	----	<200	<200	<1500	<1000		
	μ'/μ_o	----	7.10	7.10	7.10	7.10	6.99	6.2	----	6.28	4.60	1.96	0.98		
	tan δ_m	----	----	----	----	10	20	65	----	3000	6700	14,500	20,600		

a. Haveg. b. Minnesota Mining. c. Polymer Corp.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I B 3. Miscellaneous organics (cont.)		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
"Ferrotron" 308 (rod)[a]	ϵ'/ϵ_o	16.5	15.5	15.3	15.2	15.0	14.8	----	----	----	----	8.0*	----	6.3	
	$\tan\delta_d$	460	300	130	90	86	80	----	----	----	----	130*	----	150	
	μ'/μ_o	----	4.7	4.7	4.7	4.7	4.7	3.6	----	3.4	----	1.19	----	0.84	
	$\tan\delta_m$	----	----	----	----	20	80	300	----	2400	----	8900*	----	8400	
"Ferrotron" 309 (tape)[a]	ϵ'/ϵ_o	15.8	15.5	15.5	15.1	15.1	15	15	----	15	15	15	----	11	
	$\tan\delta_d$	380	250	108	58	34	29	61	----	120	<500	<1000	----	140	
	μ'/μ_o	----	----	----	----	5.54	5.65	5.4	----	4.93	3.56	1.60	----	0.44	
	$\tan\delta_m$	----	----	----	----	< 20	<200	350	----	3000	5300	12,900	----	24,000	
Varnish impregnated Kraft paper[b]	ϵ'/ϵ_o	----	4.5	----	----	4.0									
	tan δ	----	300	----	----	300									
Varnished glass cloth[c]	ϵ'/ϵ_o	----	3.9	----	----	3.5									
	tan δ	----	360	----	----	250									
Silicone varnished glass cloth, flexible[c,d]	ϵ'/ϵ_o	----	3.3	----	----	3.2									
	tan δ	----	82	----	----	28									
Silicone varnished glass cloth, stiff[c,d]	ϵ'/ϵ_o	----	2.8	----	----	2.8									
	tan δ	----	42	----	----	14									
I C. Liquids															
1. Inorganic															
Nitrogen -195°[e]	ϵ'/ϵ_o	----	1.45												
	tan δ	----	<2												
2. Organic															
a. Aliphatic															
"Kel-F" Alkane 464[f]	ϵ'/ϵ_o	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.54	2.54	2.51	2.30*			
	tan δ	1.4	0.2	<0.3	<0.3	<0.3	1.3	14	44	150	420	930*			
"Kel-F" Alkane 695[g]	ϵ'/ϵ_o	2.69	2.69	2.69	2.69	2.69	2.69	2.68	2.65	2.63	2.50	2.26*			
	tan δ	2.2	0.2	<0.3	< 1	0.7	7	70	190	470	870	890*			

a. Polymer Corp. b. ASTM type A paper (D 1305), vacuum-impregnated with Sterling M50 (Sperry test sample). c. Sperry test sample. d. R-63 varnish (Union Carbide and Carbon). e. Cryogenic Eng. Lab, M.I.T. f. Chlorotrifluoroethylene dimer (Kellogg). g. Ibid., trimer.
*Freq = 9.5×10^9

Values of tan δ are multiplied by 10^4; frequency given in c/s.

I C. Liquids (cont.)

2. Organic

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
a. Aliphatic															
"KEL-F" Alkane 8126[a]	ϵ'/ϵ_o	2.88	2.88	2.88	2.88	2.88	2.88	2.87	2.80	2.61	2.37	2.16			
	tan δ	1.5	0.15	<0.1	<0.4	2.8	28	275	650	1080	990	684			
"KEL-F" Alkane 10157[b]	ϵ'/ϵ_o	2.88	2.88	2.88	2.88	2.88	2.88	2.70	----	2.39	2.28	2.23			
	tan δ	<0.2	<0.1	0.1	1.0	9.6	96	710	----	780	480	335			
"KEL-F" Alkane 12188[c]	ϵ'/ϵ_o	2.94	2.94	2.94	2.94	2.94	2.90	----	----	2.33	2.24	2.23			
	tan δ	<0.2	<0.1	0.6	5.7	55	550	----	----	485	330	218			
Hexane[d]	ϵ'/ϵ_o	----	----	1.84											
	tan δ	----	----	< 1											
b. Aromatic															
OS-45[e]	ϵ'/ϵ_o	2.65	2.65	2.65	2.65	2.65	2.64	2.63	----	2.48					
	tan δ	3400	336	34	21	42	41	130	----	482					
OS-59, tetra alkyl silicate	ϵ'/ϵ_o	2.46	2.46	2.46	2.46	2.46	2.46	2.46	----	2.41	2.33	2.24			
ester[e]	tan δ	12.4	1.3	0.2	<0.3	<0.6	5	50	----	324	410	380			
OS-82, monoisopropyl biphenyl[e]	ϵ'/ϵ_o	2.61	2.61	2.61	2.61	2.61	2.61	2.60	2.57	2.52	2.51				
	tan δ	150	15	1.5	<0.6	1	12	115	220	183	100				
Diisopropyl biphenyl[e]	ϵ'/ϵ_o	2.54	2.54	2.54	2.54	2.54	2.54	2.53	2.49	2.44	2.41				
	tan δ	6	0.6	0.2	<0.4	1.9	19	135	190	120	66				
"Selectron" 5084 monomer[f]	ϵ'/ϵ_o	----	----	----	----	----	----	----		----	----	3.01			
	tan δ	----	----	----	----	----	----	----		----	----	410			
"Stypol" 16B monomer[g]	ϵ'/ϵ_o	----	----	7.16	----	----	----	----	----	----	----	3.02			
	tan δ	----	----	79	----	----	----	----	----	----	----	420			
c. Petroleum oil															
Jet fuel JP-4	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	2.04*			
	tan δ	----	----	----	----	----	----	----	----	----	----	30*			

a. Chlorotrifluoroethylene tetrameter. b. Ibid., pentamer. c. Ibid., hexamer. d. Phillips. e. Monsanto (St. Louis). f. Pittsburg-Corning. g. Robertson.

*Freq = 9.5×10^9.

Values of tan δ are multiplied by 10^4; frequency given in c/s.

		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$	$1.4x10^{10}$	$2.4x10^{10}$	$5x10^{10}$
I C 2 d. Silicones															
High Vacuum Grease[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	2.80	2.74			
	tan δ	----	----	----	----	----	----	----	----	----	80	200			
DC XF-6620[a]	ϵ'/ϵ_o	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.80	2.79	2.67	2.41			
	tan δ	3	0.3	<0.1	<0.1	<0.2	1.7	17	48	103	180	217			
I D. Gases															
Nitrogen 14.7 psi[b]	ϵ'/ϵ_o	----	----	1.00058	----	----	----	----	----	1.00058	1.00058				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
1000 psi	ϵ'/ϵ_o	----	----	1.0403	----	----	----	----	----	1.0403	1.0403				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
2000 psi	ϵ'/ϵ_o	----	----	1.0807	----	----	----	----	----	1.0807	1.0807				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
3000 psi	ϵ'/ϵ_o	----	----	1.210	----	----	----	----	----	1.210	1.210				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
4000 psi	ϵ'/ϵ_o	----	----	1.563	----	----	----	----	----	1.563	1.563				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
5000 psi	ϵ'/ϵ_o	----	----	1.857	----	----	----	----	----	1.857	1.857				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				
Nitrous oxide 14.7 psi[c]	ϵ'/ϵ_o	----	----	1.0030	----	----	----	----	----	1.0030	1.0030				
	tan δ	----	----	< 1	----	----	----	----	----	< 10	< 10				

a. Dow-Corning. b. Purified (Air Reduction). c. Olin Mathieson.

II. SUPPLEMENT TO DATA AT ROOM TEMPERATURE

A. Materials measured too late for inclusion in Section I

Values of tan δ are multiplied by 10^4; frequency given in c/s.

Ceramics		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$
"AFC" Alumina[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.28
	tan δ	----	----	----	----	----	----	----	----	----	----	9.4
"AlSiMag" 544[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	7.69
(Supercedes previous sample)	tan δ	----	----	----	----	----	----	----	----	----	----	16
"AlSiMag" 548 dried[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	5.51
	tan δ	----	----	----	----	----	----	----	----	----	----	1.0
"AlSiMag" 602 (dried)[c]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	4.62
	tan δ	----	----	----	----	----	----	----	----	----	----	18
"AlSiMag" 652[b]	ϵ'/ϵ_o	9.21	9.19	9.18	9.18	9.18	9.18	9.18				
	tan δ	74	11.5	4.2	2	0.8	0.15	< 1				
Beryllium oxide, hot pressed[d]	ϵ'/ϵ_o	5.58*	5.57*	5.55*	5.54*	5.54*	5.54*	5.54*	----	----	----	5.62
(d = 2.560 gm/cc)	tan δ	110*	34*	5*	3*	1.8*	1.3*	1.8*	----	----	----	10.4
Beryllium oxide, crucible grade[d]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	3.55
(d = 1.784 gm/cc)	tan δ	----	----	----	----	----	----	----	----	----	----	14.9
Coors AI-200 (1956 production)	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.63
	tan δ	----	----	----	----	----	----	----	----	----	----	11.6
"Alite" AP-212[e]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.25
	tan δ	----	----	----	----	----	----	----	----	----	----	8.6
"Alite" AP-216[e]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.03
	tan δ	----	----	----	----	----	----	----	----	----	----	13
"Alite" AP-312[e]	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	8.42
	tan δ	----	----	----	----	----	----	----	----	----	----	11.5

a. Amer. Feldmuehle. b. Alumina (Amer. Lava). c. Lava (Amer. Lava). d. Beryllium Corp. e. Alumina (U.S. Stoneware).

*Mottled sample d = 2.546.

II. SUPPLEMENT TO DATA AT ROOM TEMPERATURE (Cont.)

A. Materials measured too late for inclusion in Section I

Values of tan δ are multiplied by 10^4; frequency given in c/s.

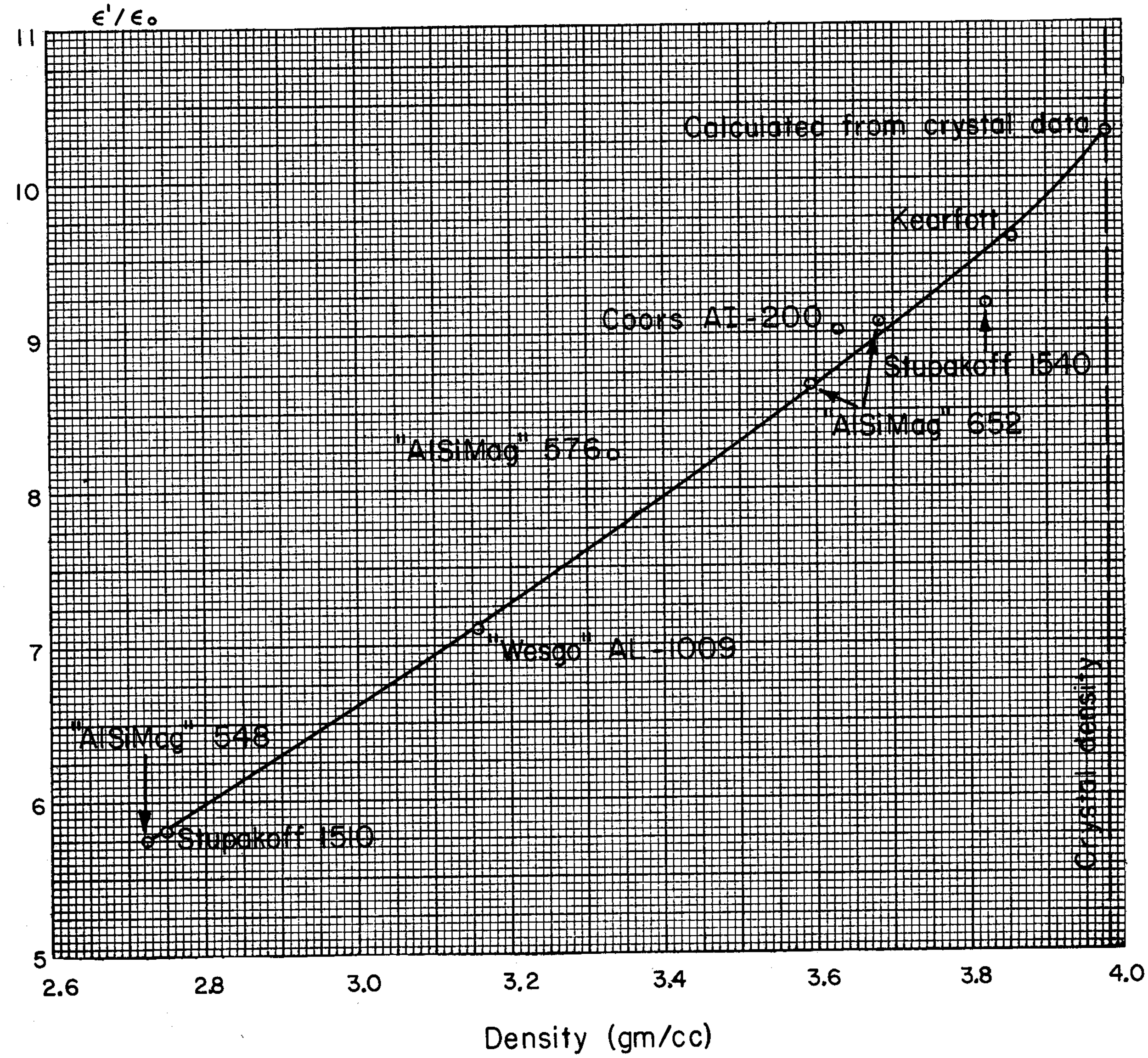
Plastics		$1x10^2$	$1x10^3$	$1x10^4$	$1x10^5$	$1x10^6$	$1x10^7$	$1x10^8$	$3x10^8$	$1x10^9$	$3x10^9$	$8.6x10^9$
"Markite" 3985	ϵ'/ϵ_o	----	----	----	----	----	----	----	----	----	----	40
	tan δ	----	----	>400*	> 20*	> 10*	> 60*	----	----	----	----	3.0*
	(ohm-cm)		----	1.73	1.73	1.73	1.73	----	----	----	----	1.7
"Markite" 12812	ϵ'/ϵ_o	----	----	----	----	----	1200	----	----	----	----	21
	tan δ	----	----	$>10^{5}$*	----	----	> 5*	----	----	----	----	1.5*
	(ohm-cm)		----	16.4	16.4	16.0	15.8	----	----	----	----	6.6
"Scotchply" 1002, isotropic[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	4.56	4.53	4.51	4.48
	tan δ	----	----	----	----	----	----	----	158	162	167	175
"Scotchply" 1002, crossply[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	4.42	4.40	4.39	4.38
	tan δ	----	----	----	----	----	----	----	164	177	186	200
"Scotchply" 1002, unidirectional[a]	ϵ'/ϵ_o	----	----	----	----	----	----	----	4.35	4.32	4.28	4.24
	tan δ	----	----	----	----	----	----	----	171	171	172	173
"Scotchply" XPM-107[b]	ϵ'/ϵ_o	----	----	----	----	----	----	----	4.31	4.30	4.29	4.28
	tan δ	----	----	----	----	----	----	----	129	162	181	202

a. Polyester "fiberglas" laminate (Minn. Mining) b. Epoxy - "fiberglas" laminate (Minn. Mining).

*tan δ not mulitplied by 10^4.

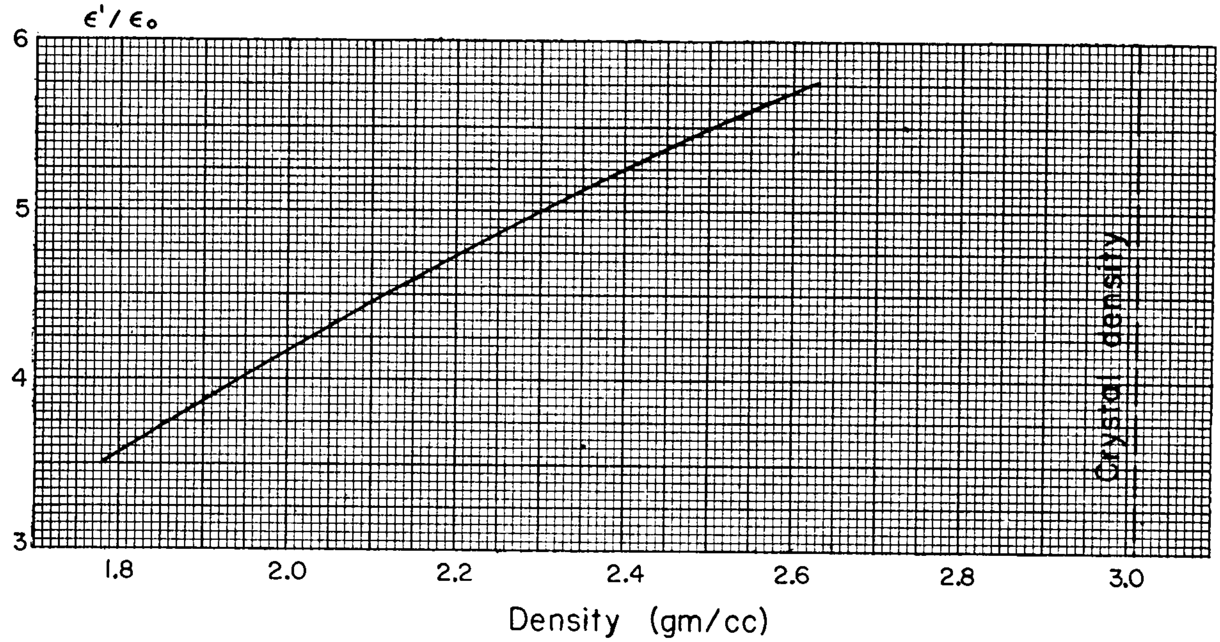
II B.

Dielectric Constant vs. Density for High Alumina Bodies at 26°C

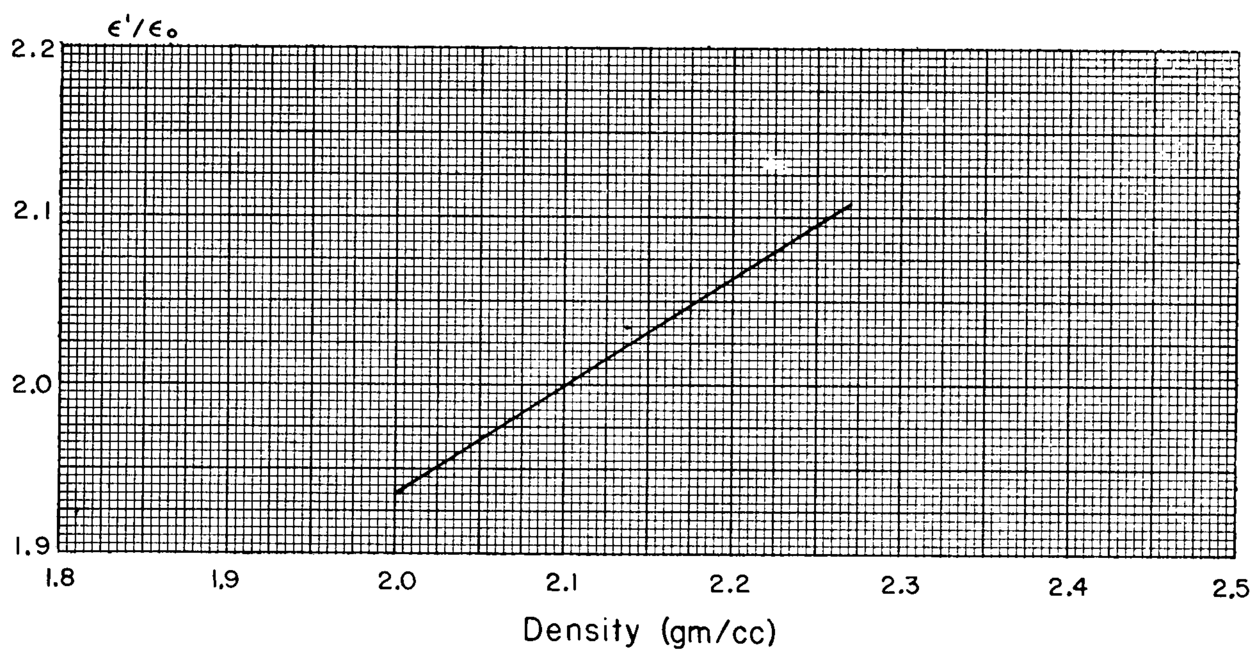


II B.

Dielectric Constant vs. Density for Beryllia Bodies at 26°C



Dielectric Constant vs. Density for "Teflon" at 26°C



III. Data at Fixed Frequencies as a Function of Temperature

Previous to this volume of the "Tables," the highest temperature of measurements has not exceeded, with few exceptions, the long-time thermal stability temperature for each material.

In the present volume, data have been taken on several laminates at temperatures above normal, For these, the time intervals of measurement are indicated. The samples were measured in partial vacuum in order to withdraw gaseous decomposition products.

Other curves showing data with increasing and decreasing temperatures, particularly with ceramics, indicate changes due to water loss since the sample is not in equilibrium with room humidity at the end of the run. The change in electrical properties with water loss is a reversible process more easily demonstrated in the microwave region, where it is mainly a volume effect, than at low frequencies where it is mainly a surface effect.

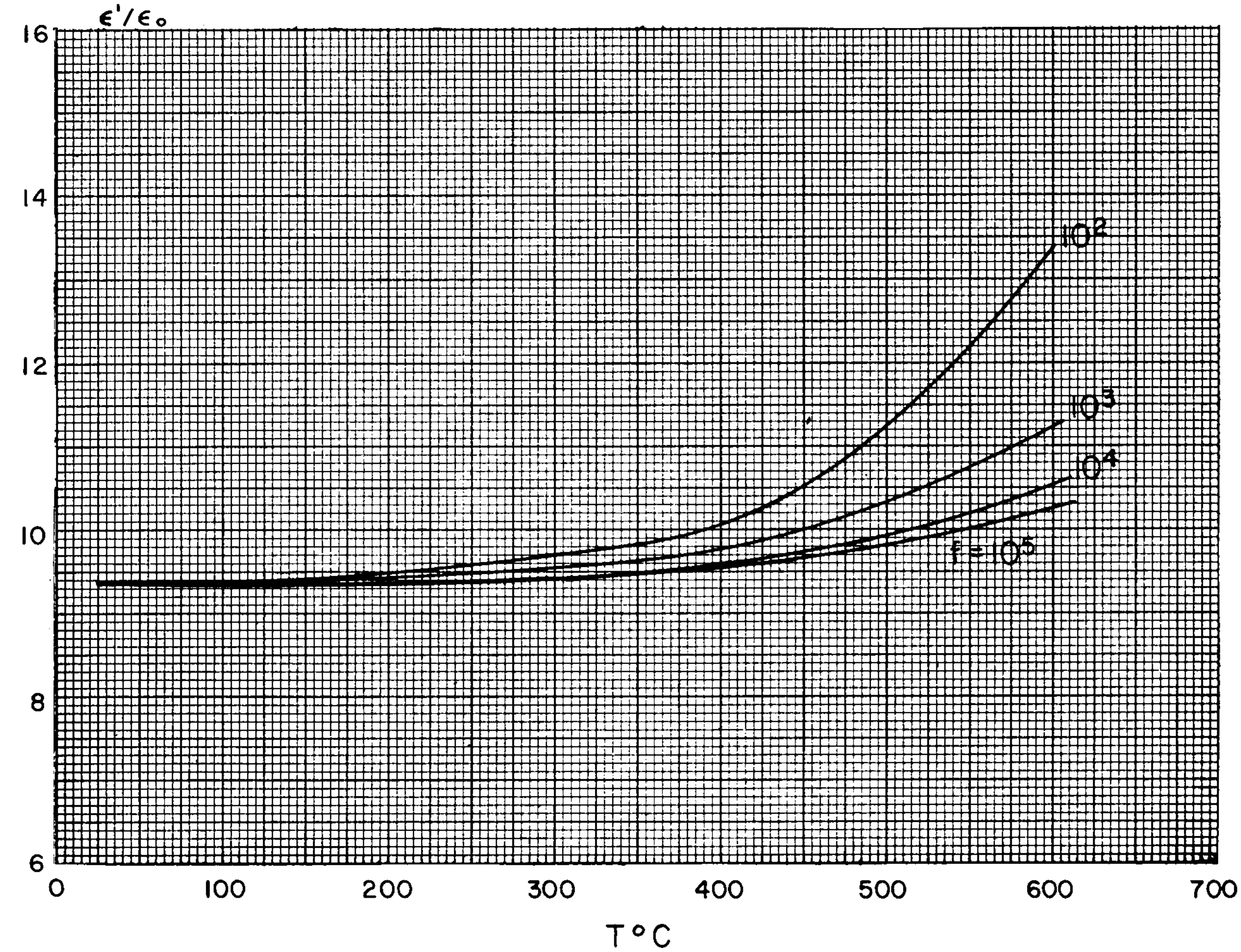
As in the room temperature measurements, the electric field direction is perpendicular to the plane of laminates for frequencies in the range 10^2 through $3x10^8$ c/s; it is parallel to or in the plane of the laminate for all higher frequencies unless otherwise specified.

The measuring frequency for the curves marked $f = 10^{10}$ was 8.5 kMc .

III A 1. Crystals

Aluminum oxide crystal, sapphire
Field perpendicular to optical axis

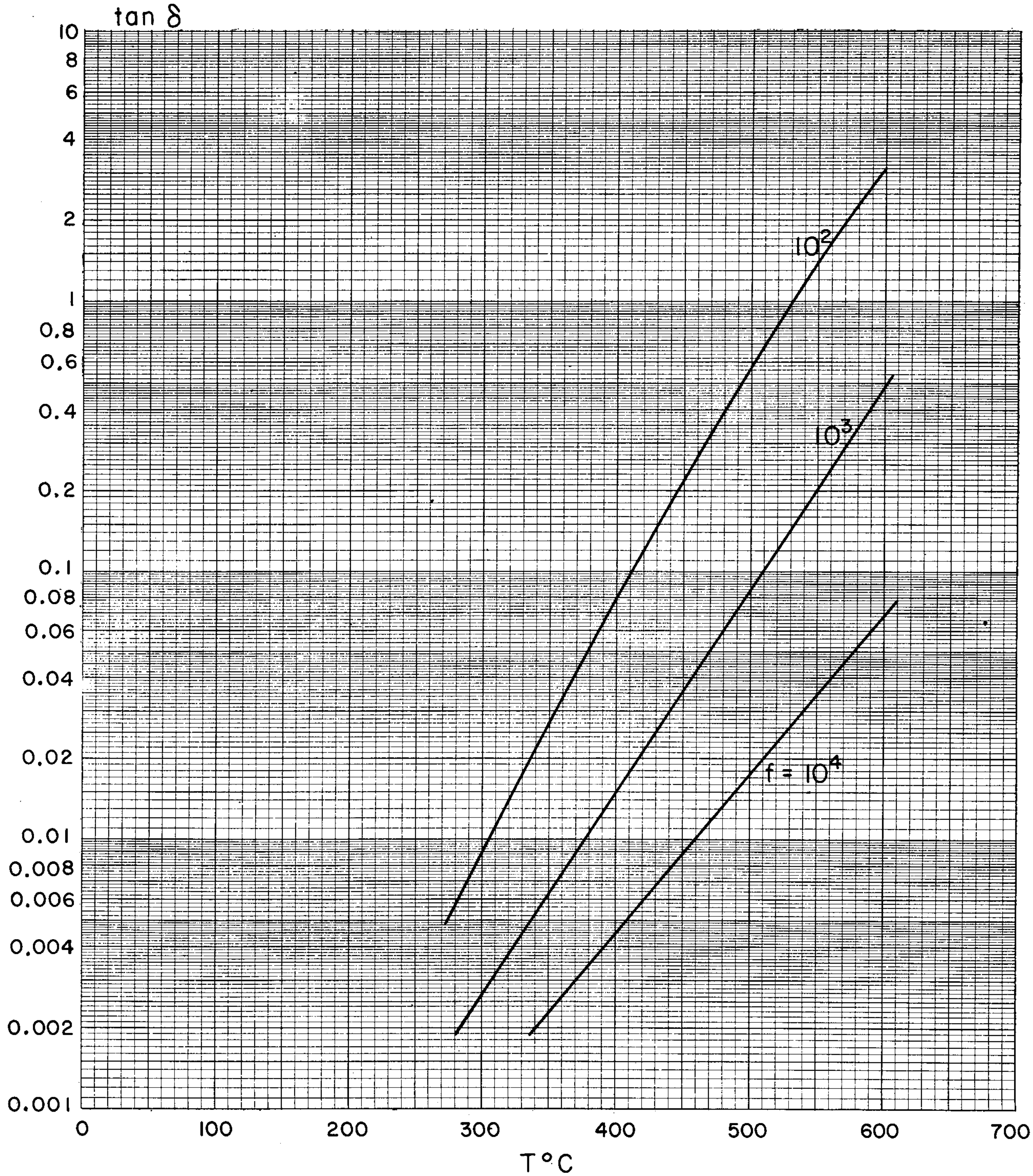
Linde Air



III A 1. Crystals

Aluminum oxide crystal, sapphire
Field perpendicular to optical axis

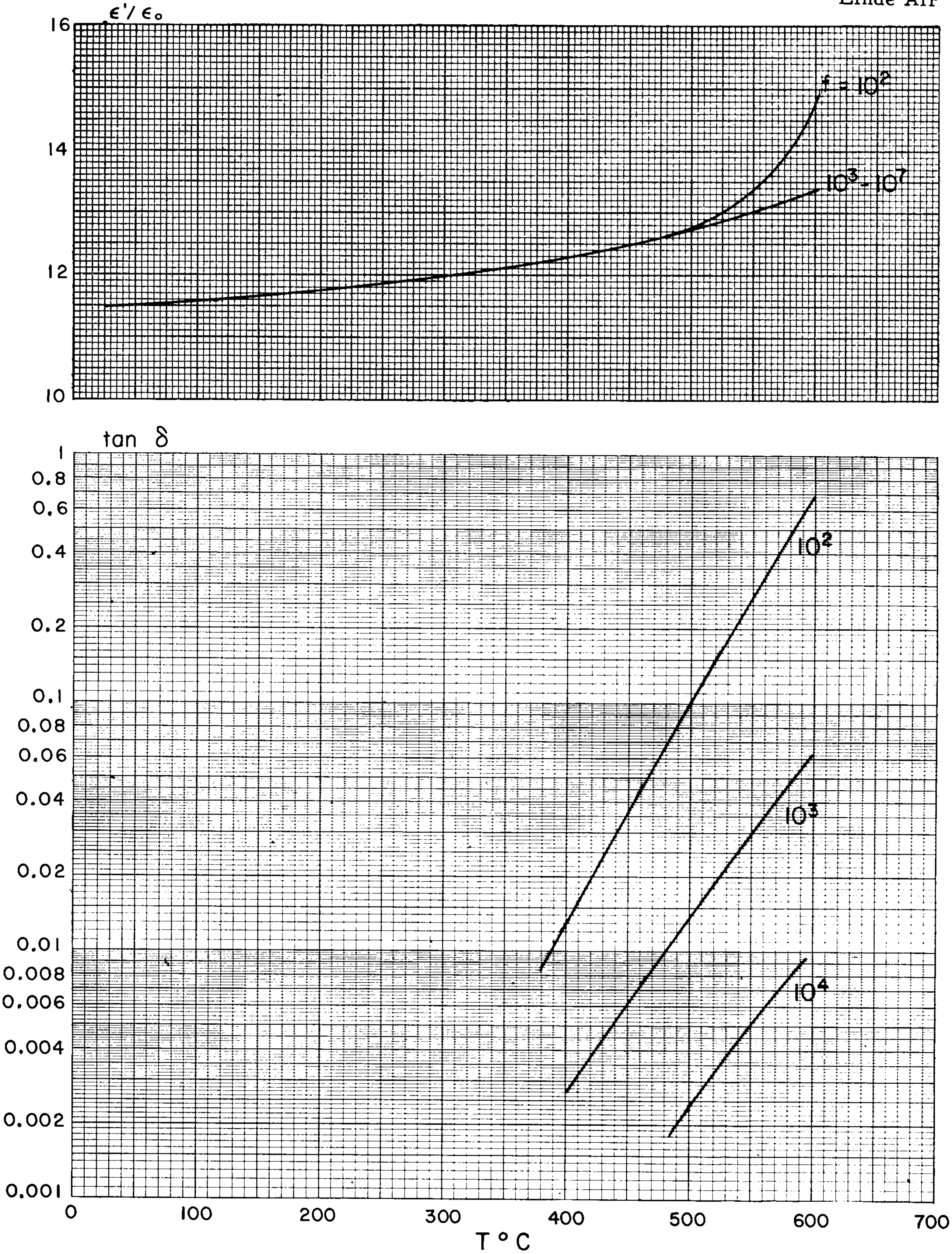
Linde Air



III A 1. Crystals

Aluminum oxide crystal (field parallel to optical axis)

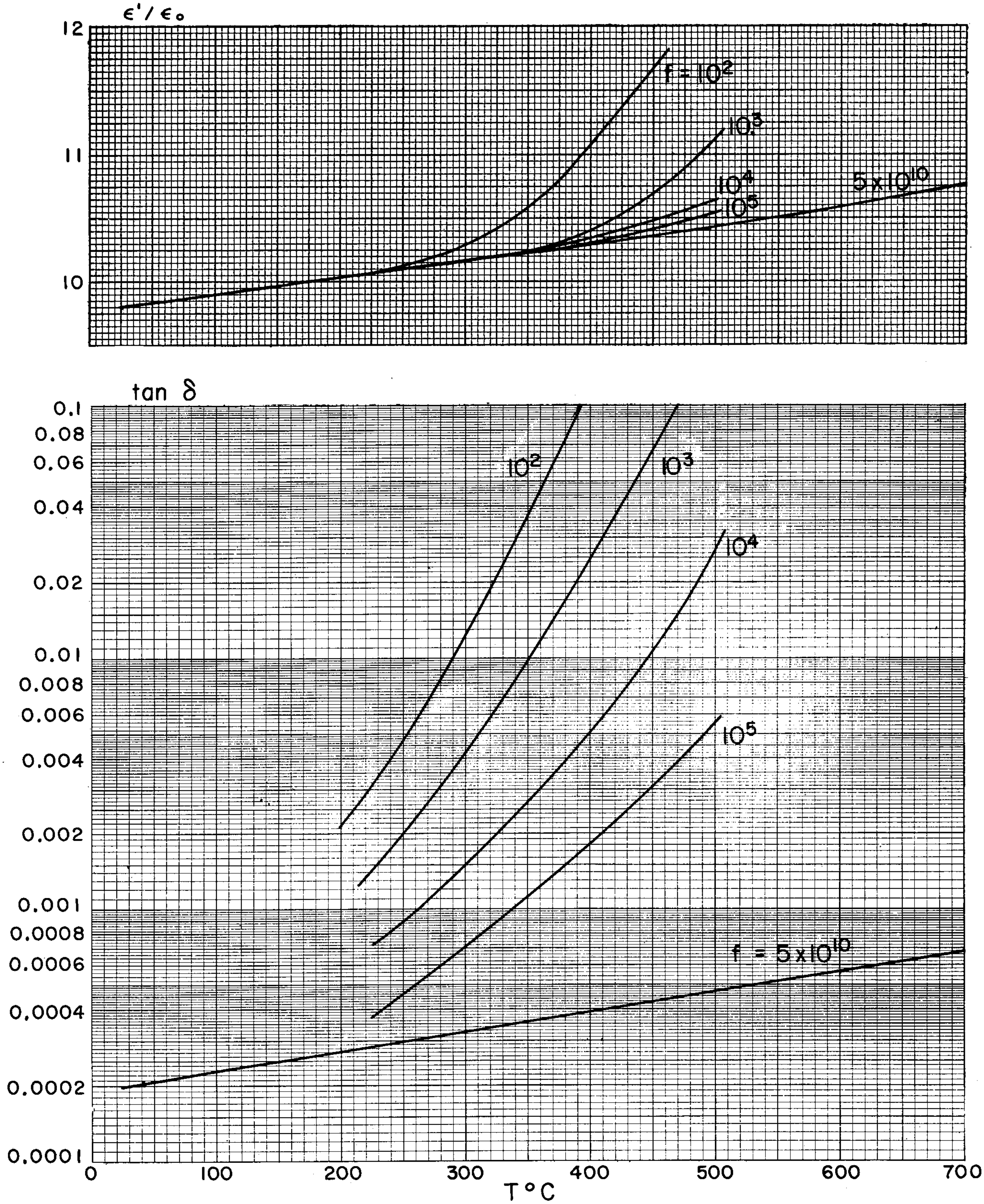
Linde Air



III A 1. Crystals

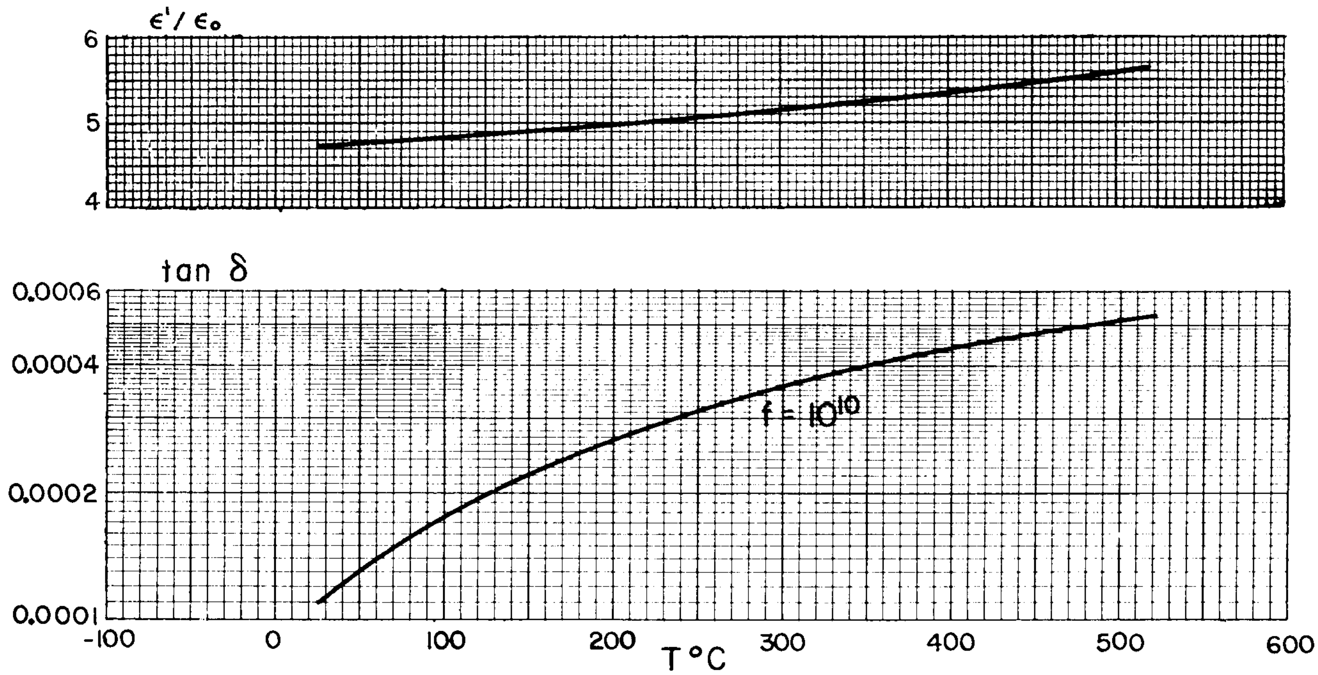
Magnesium oxide crystal

Norton



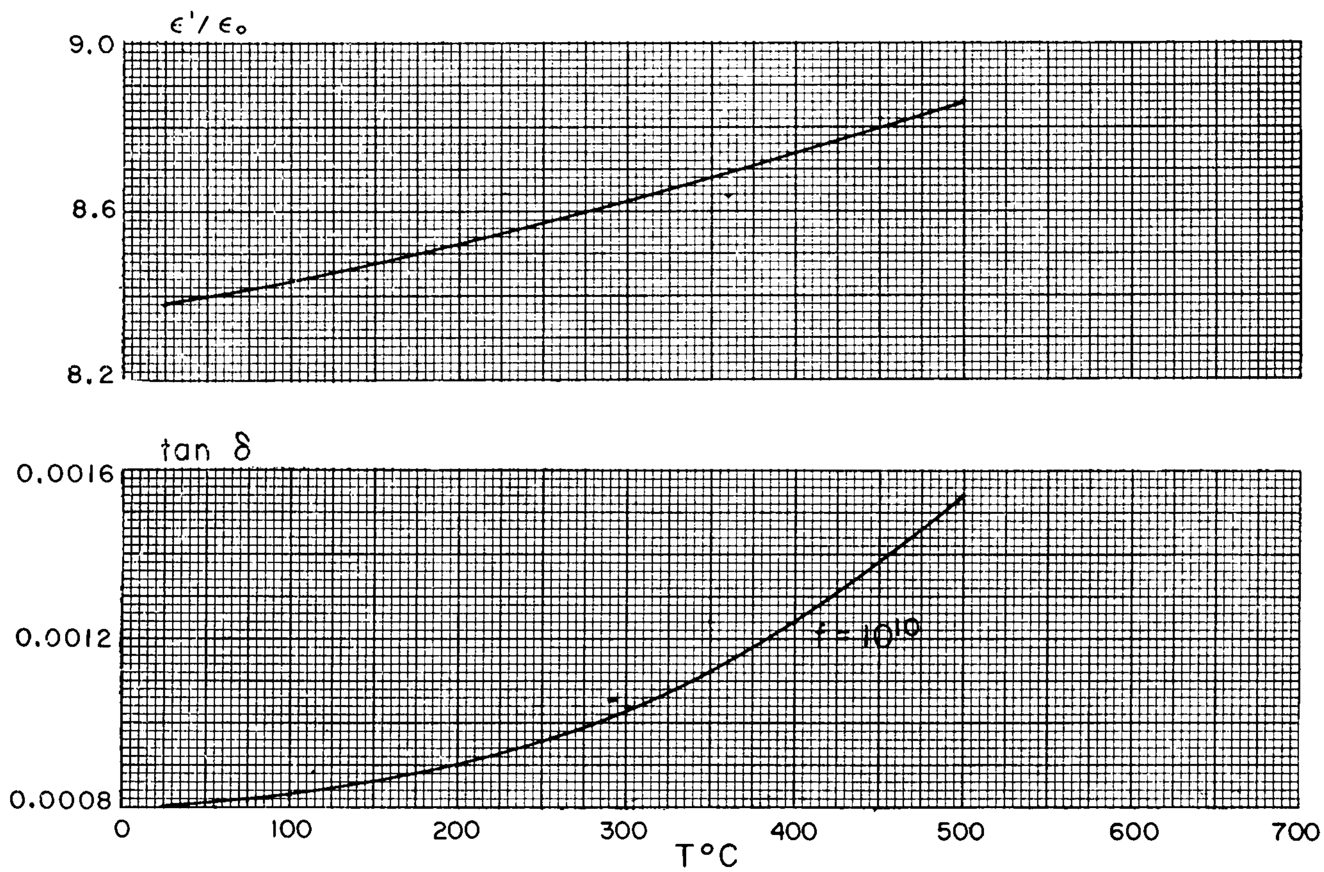
III A 1. Crystals

Potassium Chloride | Harshaw



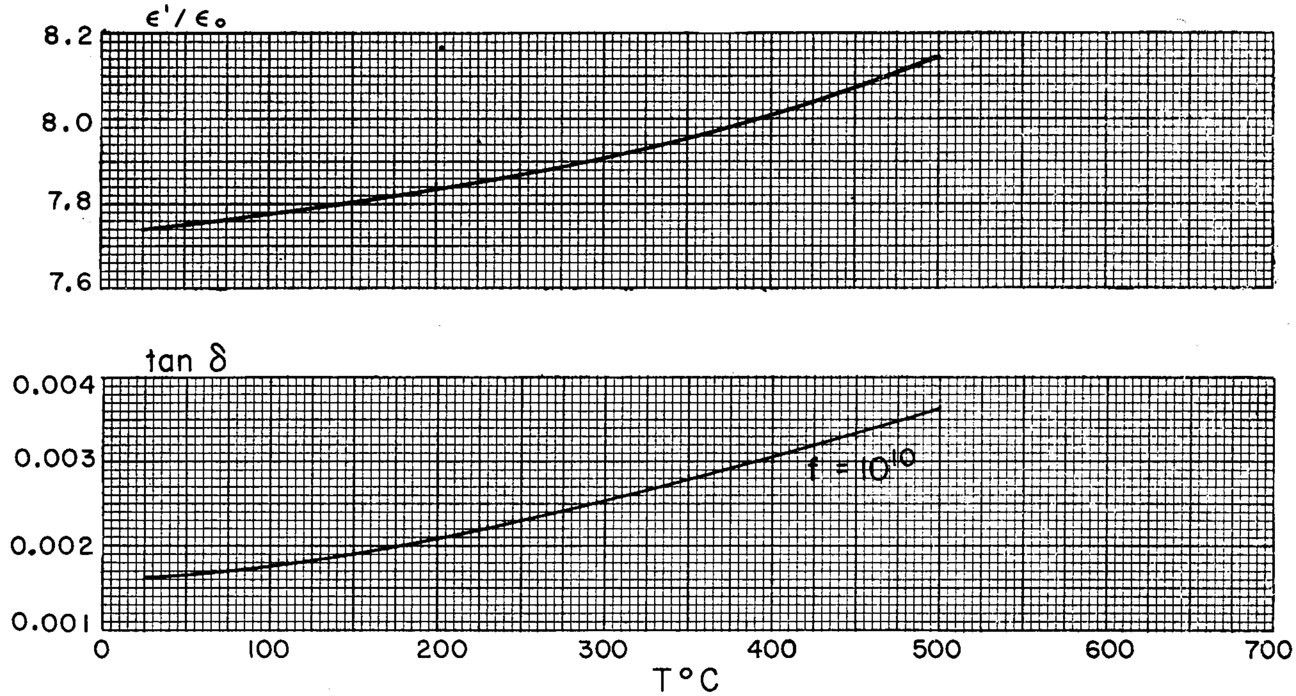
III A 2 a. Aluminas

"AFC" | American Feldmuehle

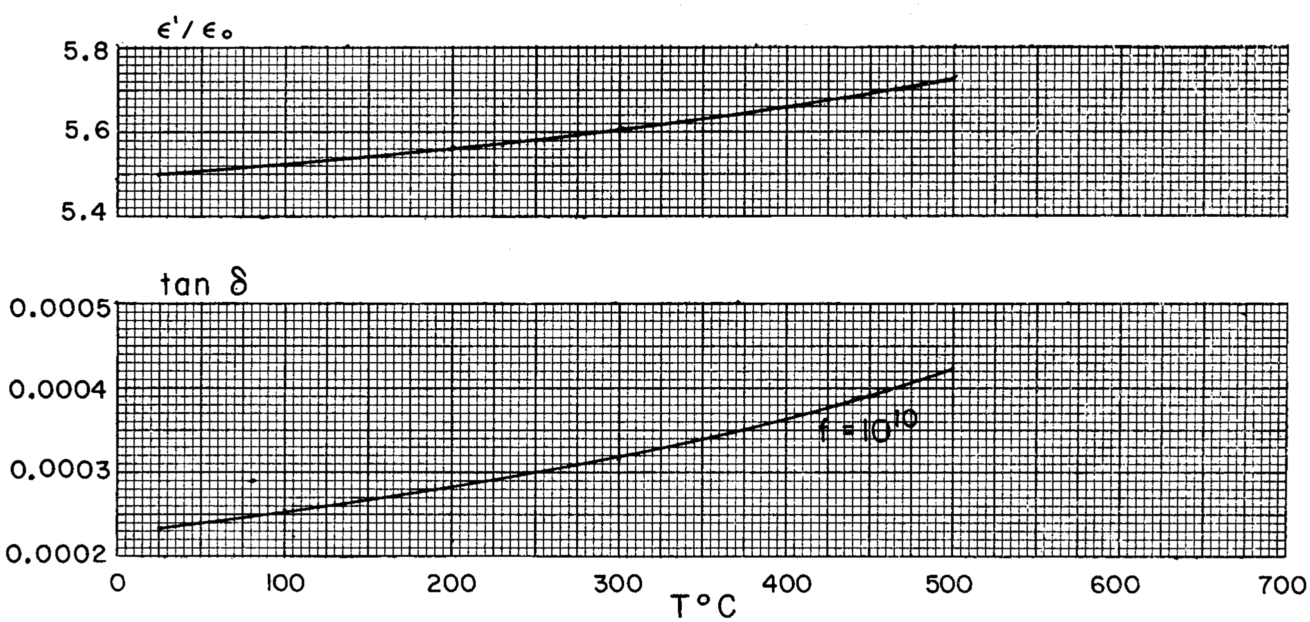


III A 2 a. Aluminas

"AlSiMag" 544 American Lava



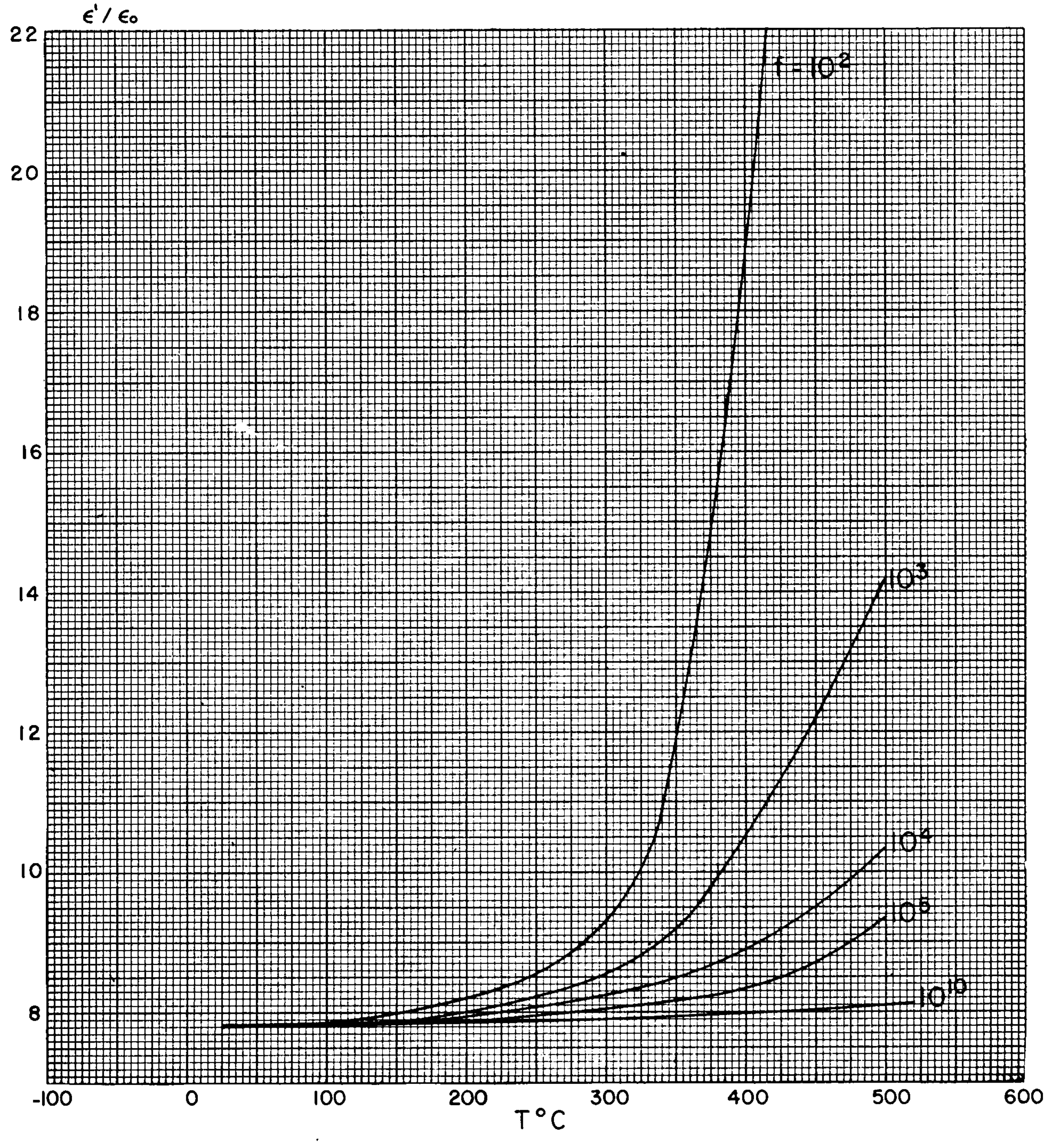
"AlSiMag" 548 American Lava



III A 2 a. Aluminas

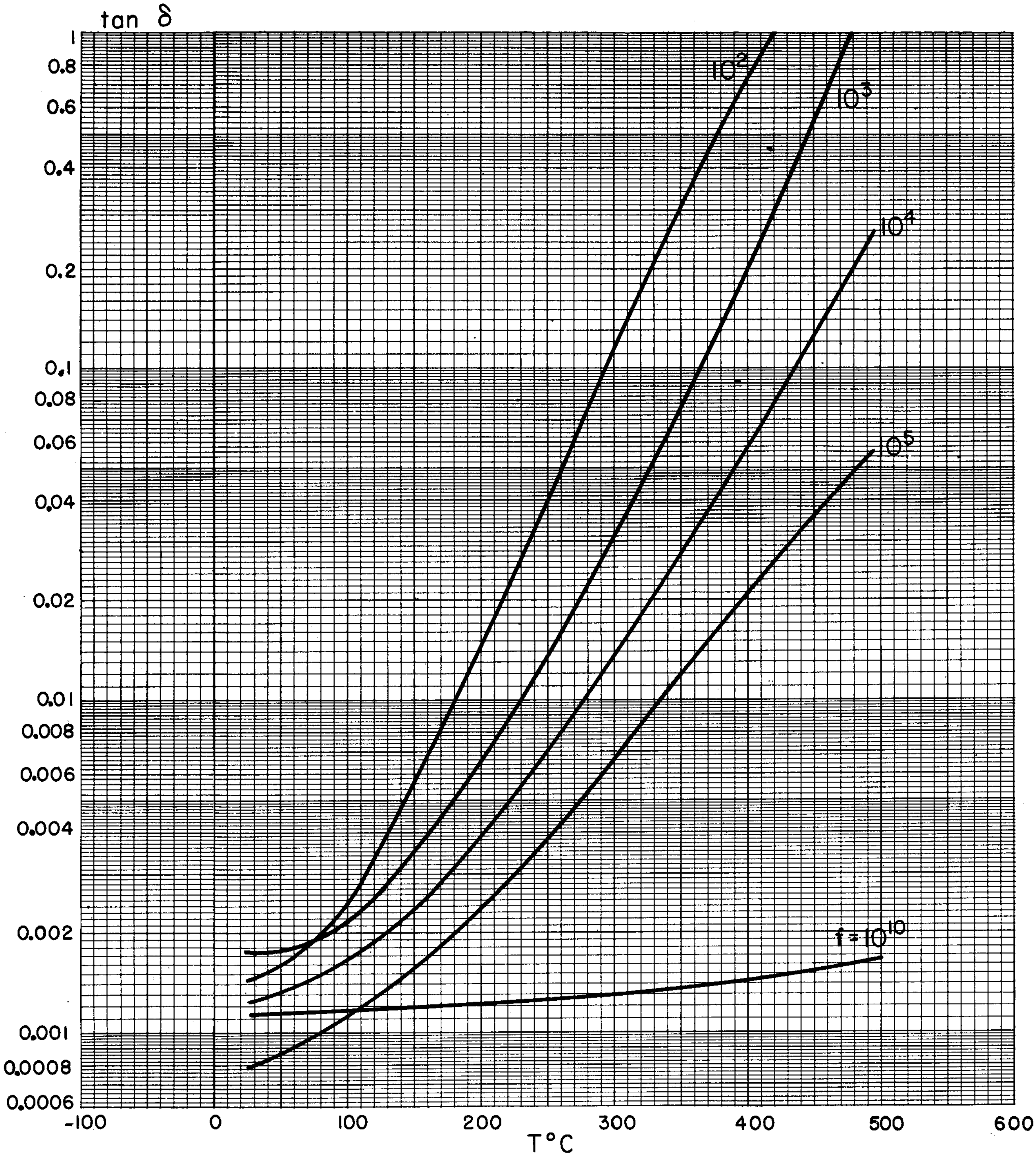
"AlSiMag" 491 (blue)

American Lava



III A 2 a. Aluminas

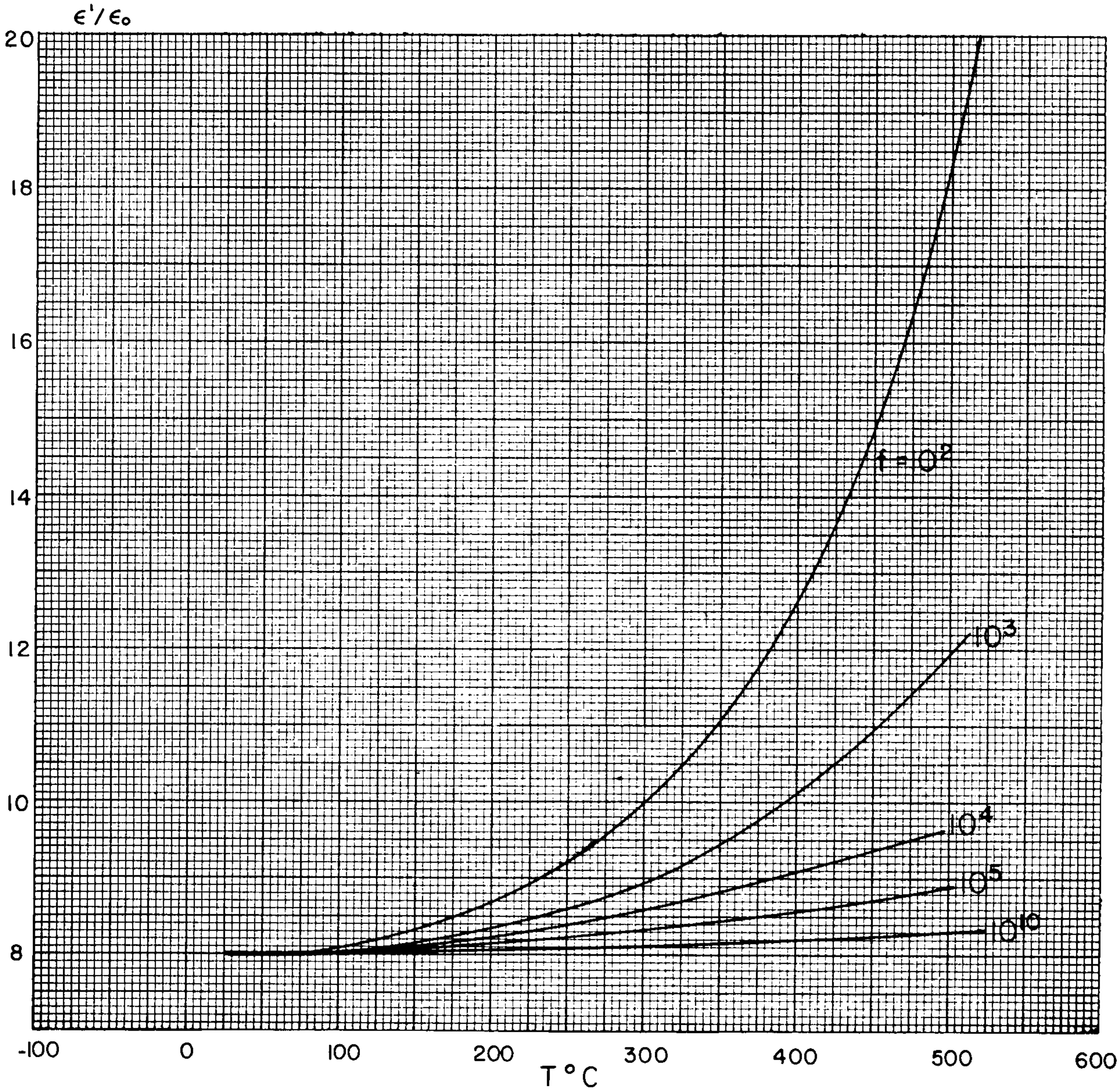
"AlSiMag" 491 (blue) American Lava



III A 2 a. Aluminas

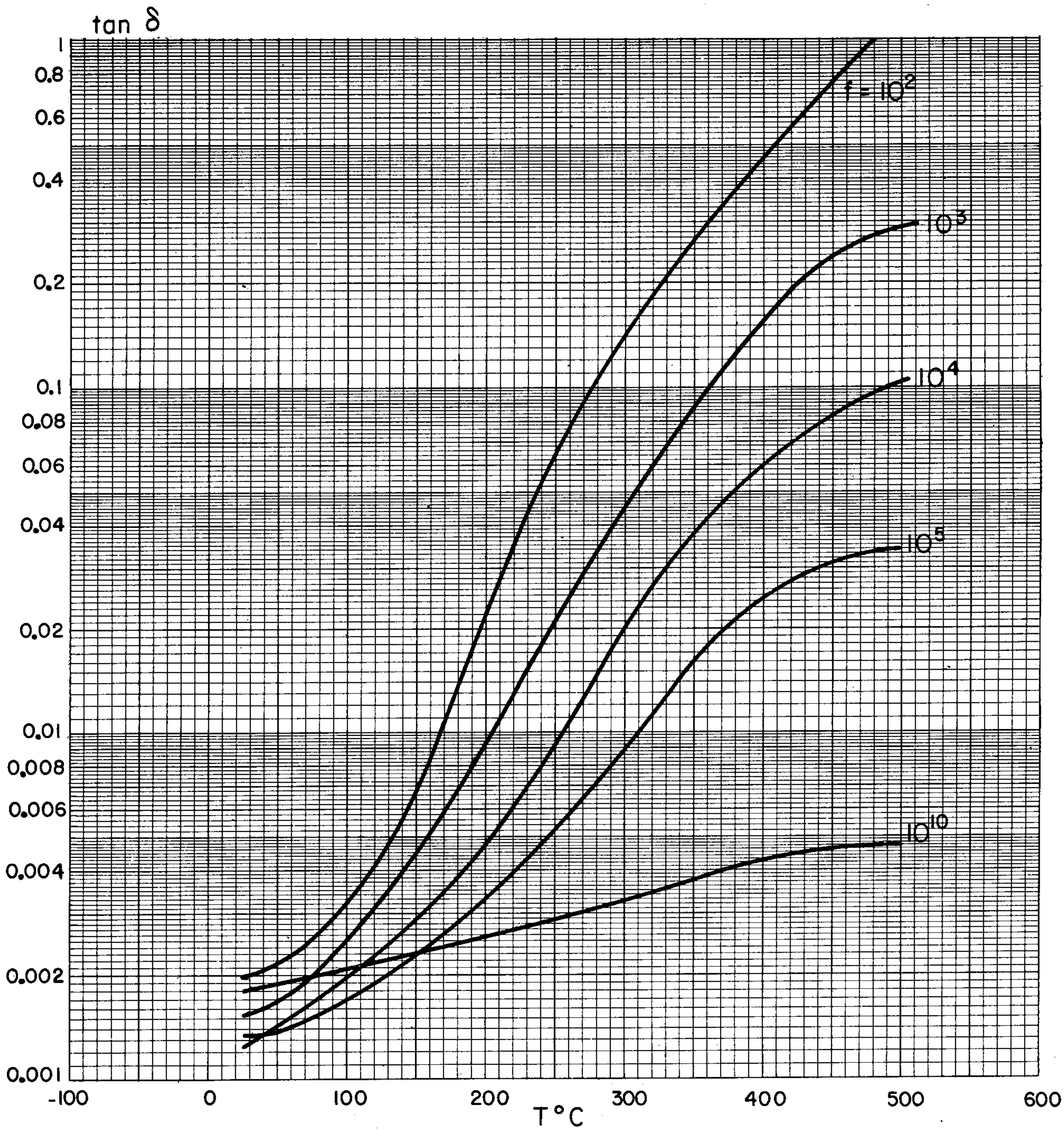
"AlSiMag" 513 (pink)

American Lava



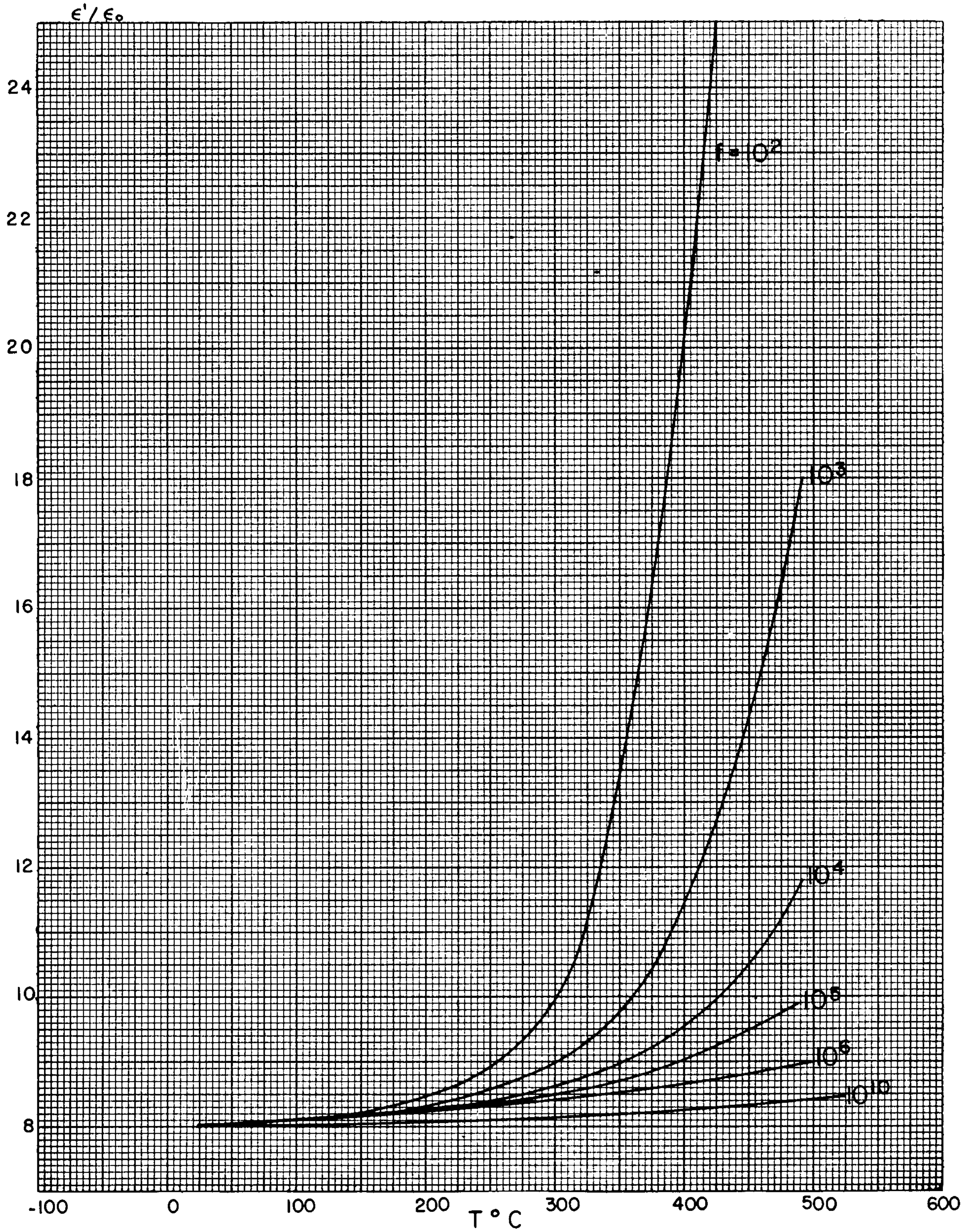
III A 2 a. Aluminas

"AlSiMag" 513 (pink) American Lava



III A 2 a. Aluminas

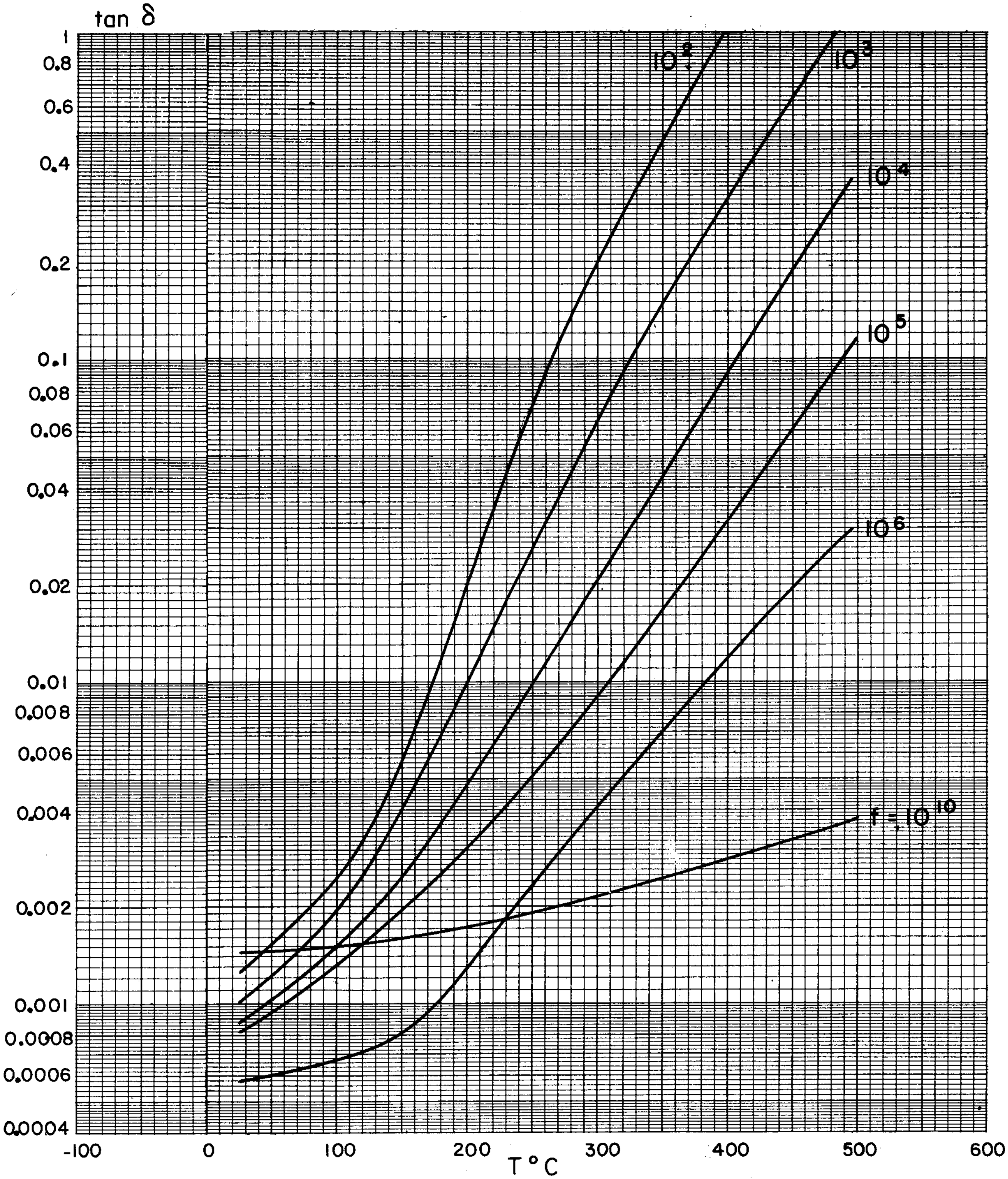
"AlSiMag" 576 American Lava



III A 2 a. Aluminas

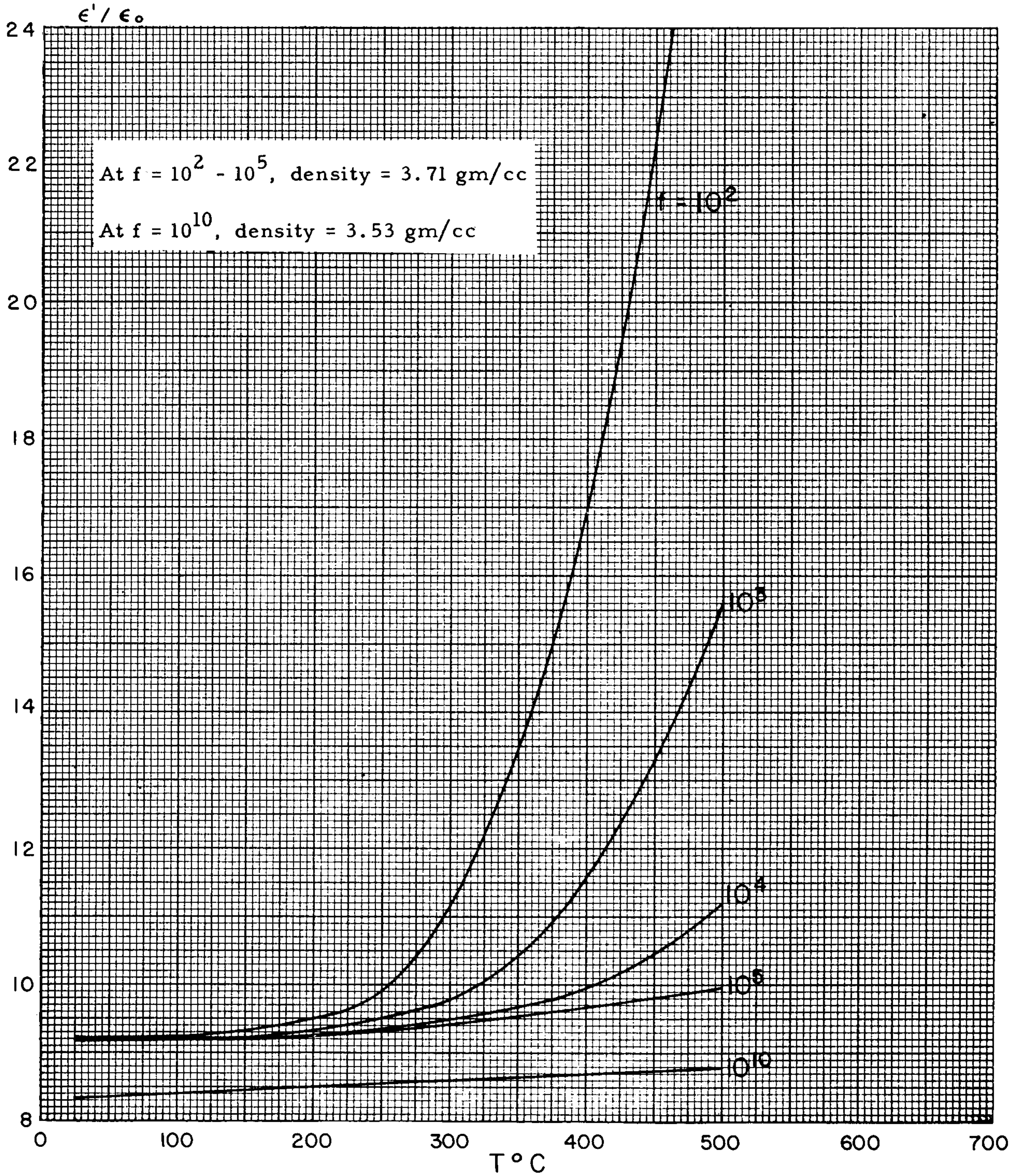
"AlSiMag" 576

American Lava



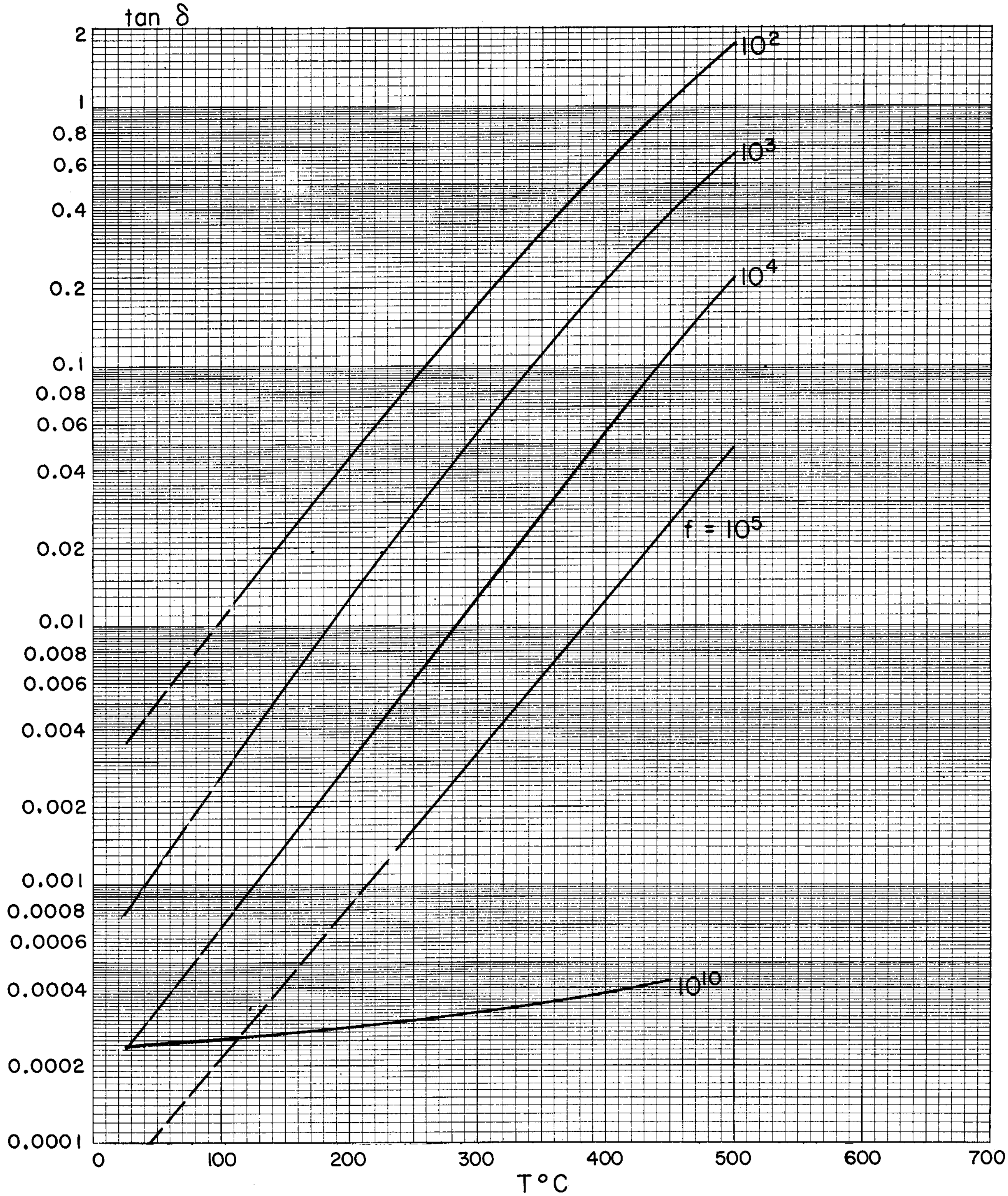
III A 2 a Aluminas

"AlSiMag" 652 American Lava



III A 2 a. Aluminas

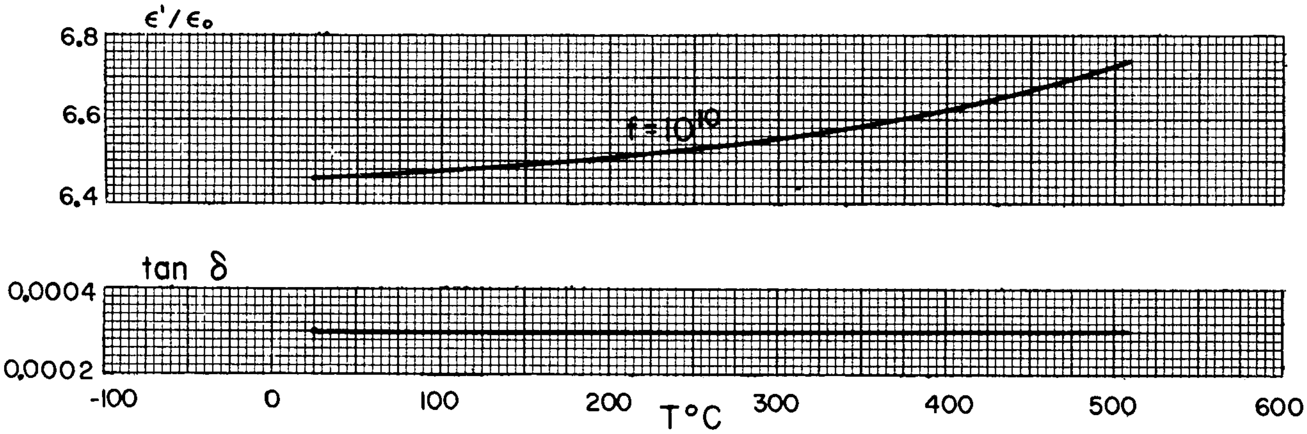
"AlSiMag" 652 American Lava



III A 2 a. Aluminas

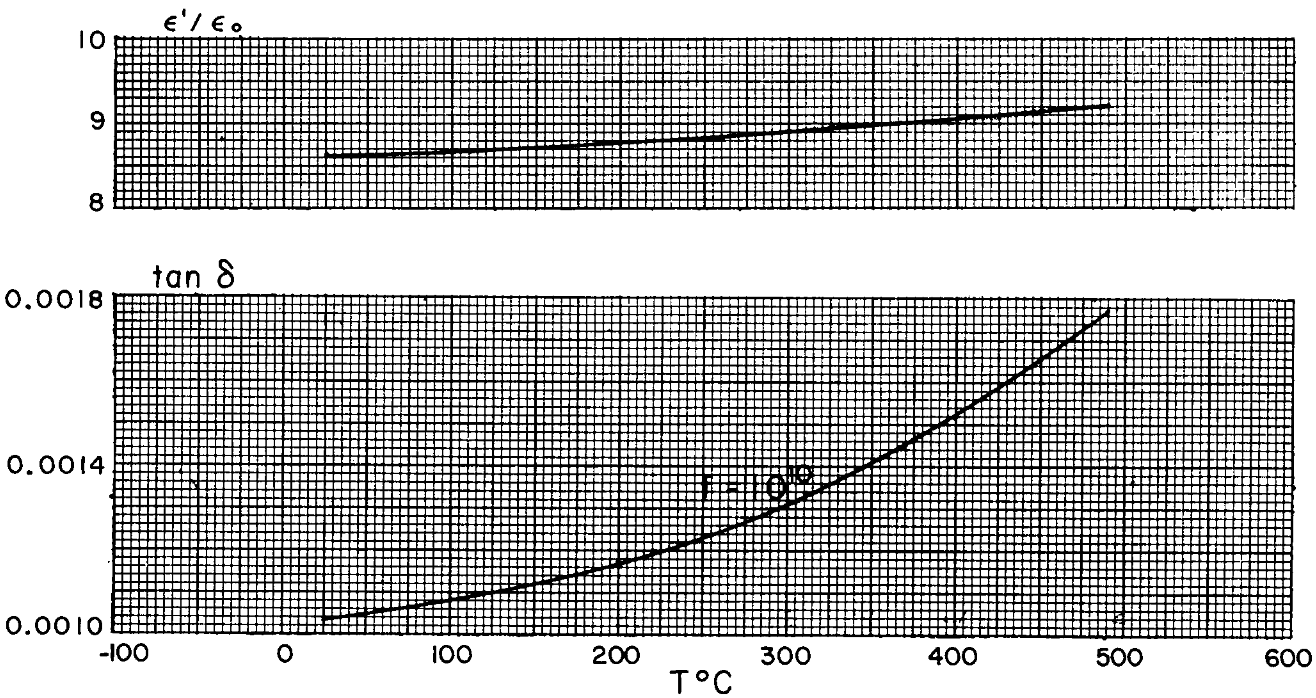
Coors AL-100

Coors



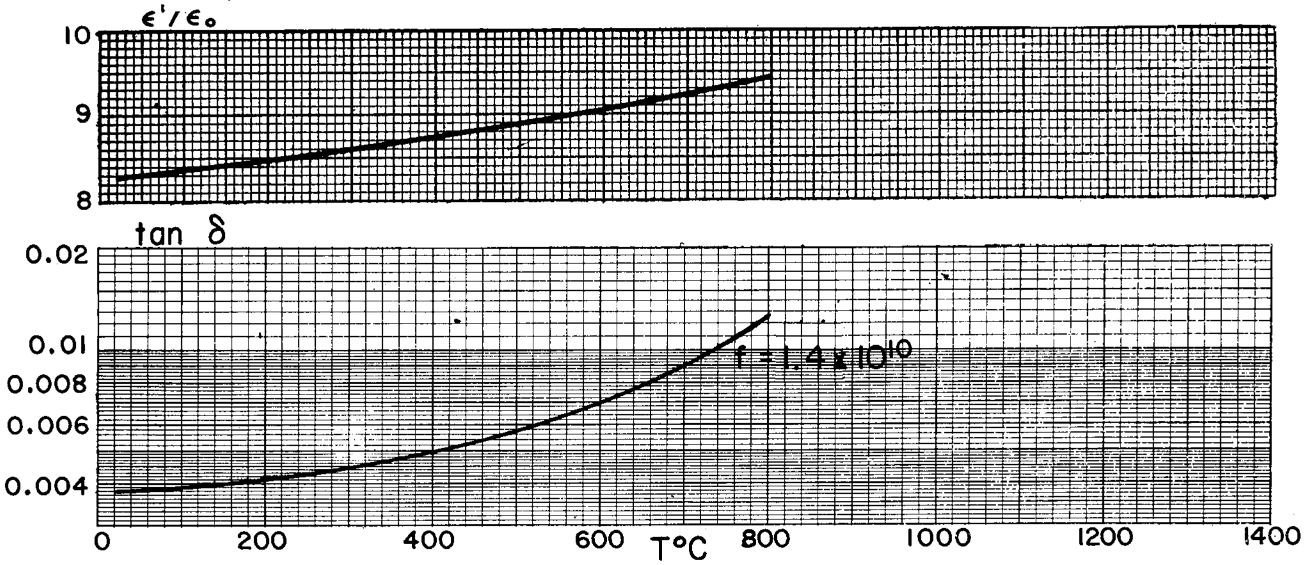
Coors AI-200 (1956)

Coors

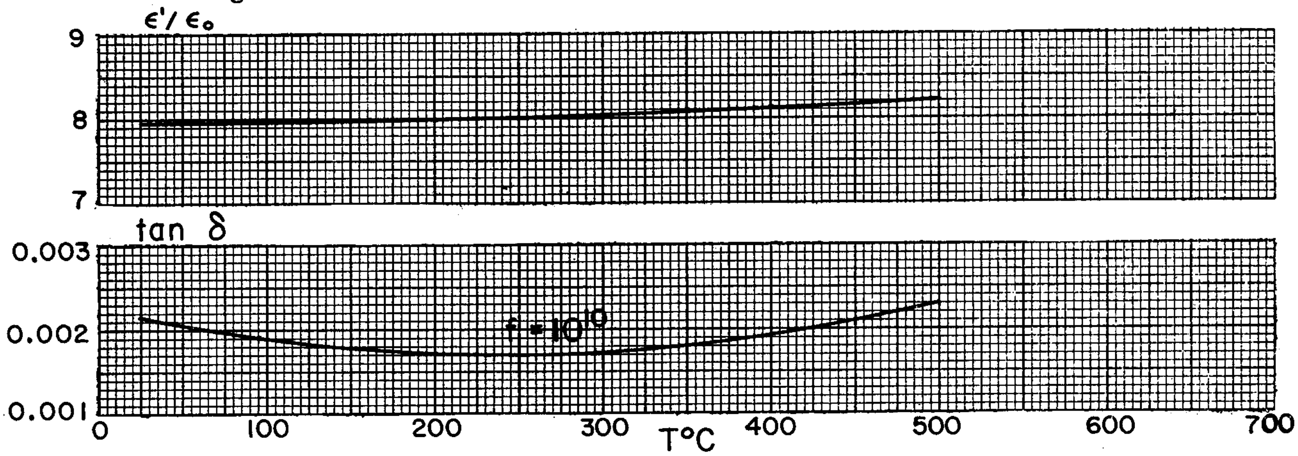


III A 2 a. Aluminas

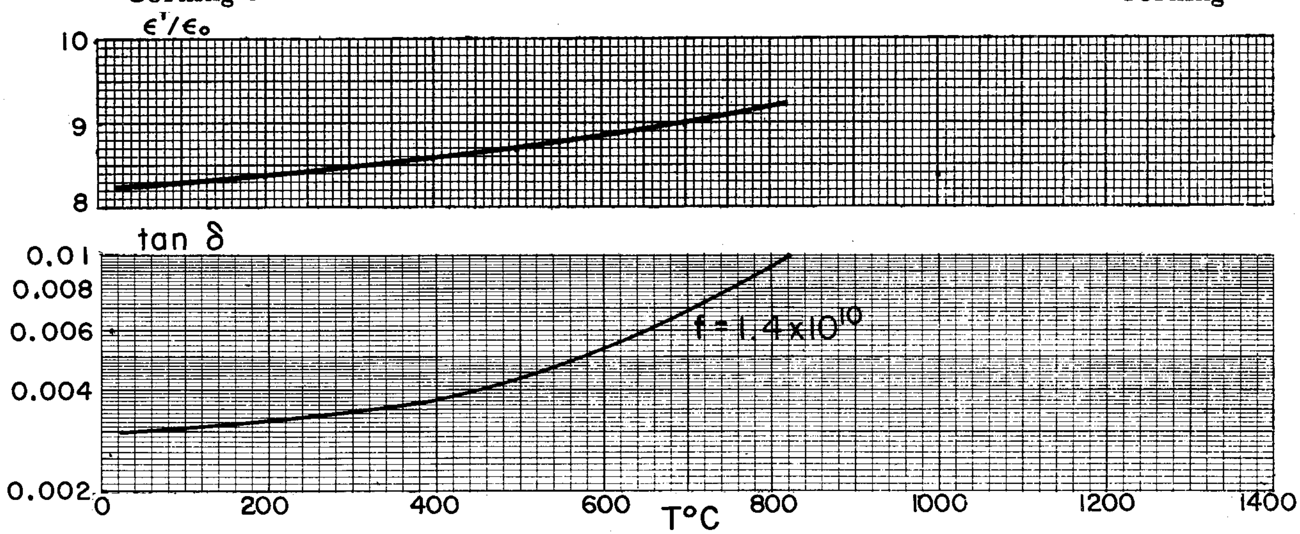
Corning JD-40 | Corning



Corning JD-82 | Corning



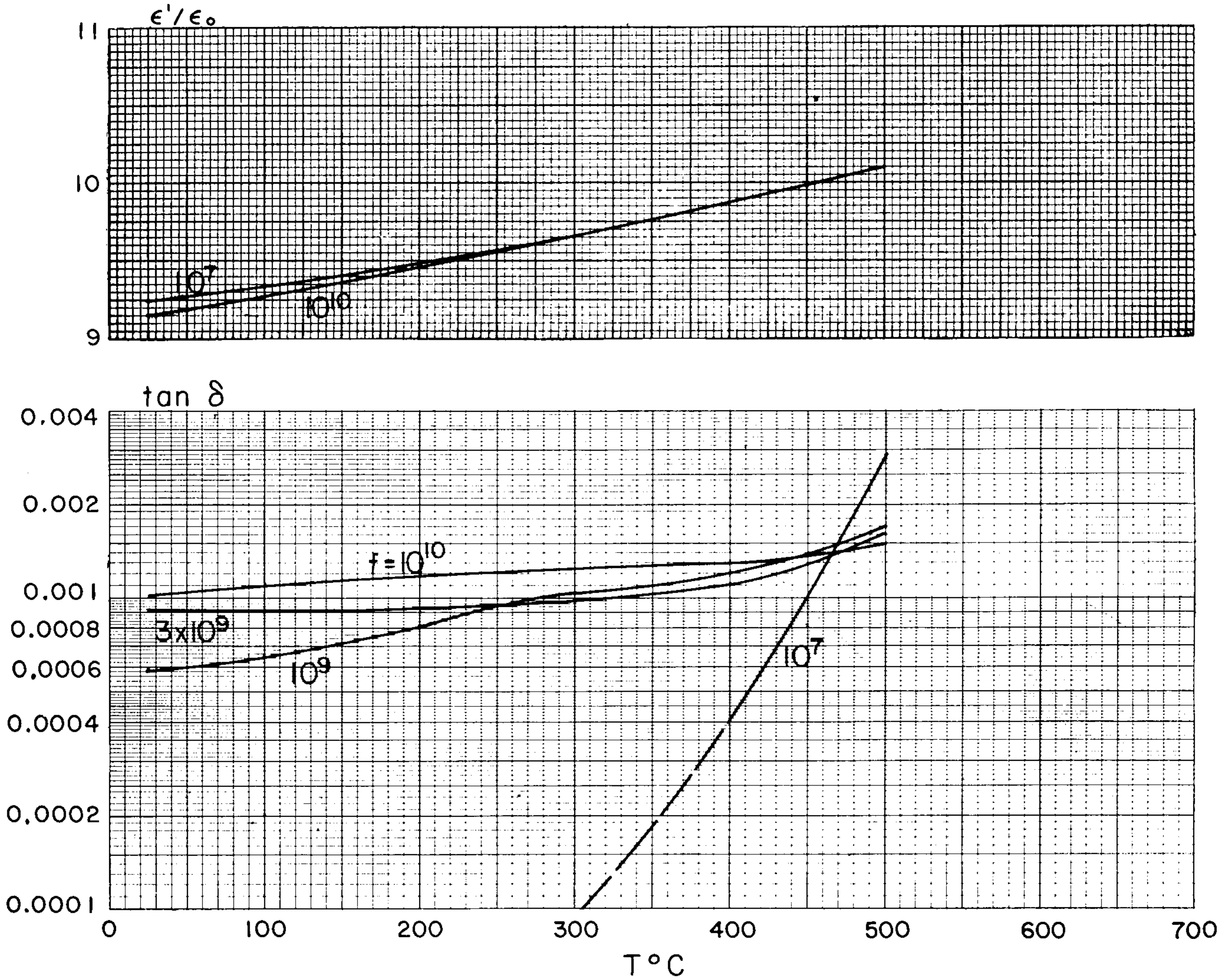
Corning JB-183 | Corning



III A 2 a. Aluminas

"Diamonite" B-890

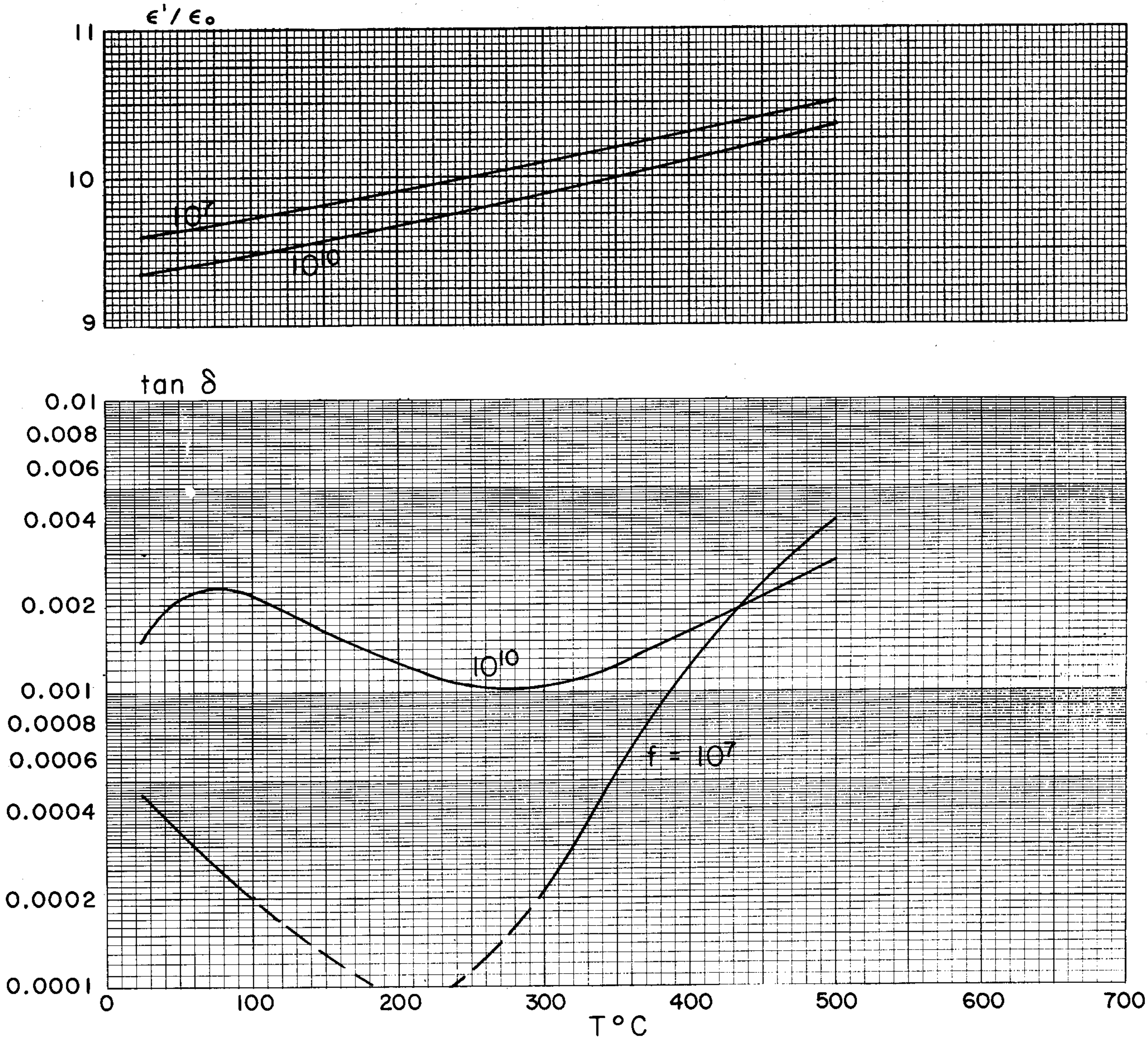
Diamonite Products Div.
U.S. Ceramic Tile



III A 2 a. Aluminas

"Diamonite" P-3142

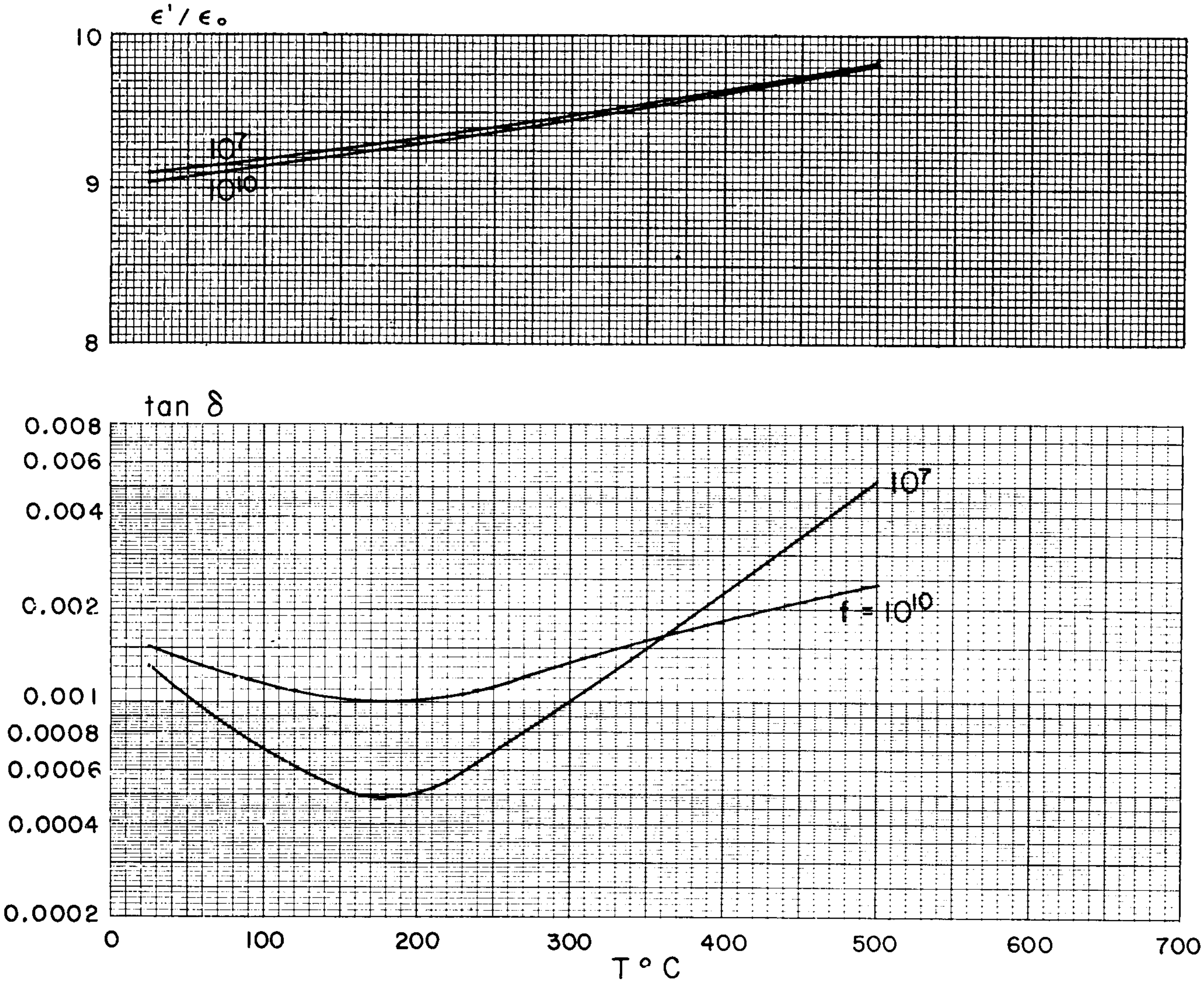
Diamonite Products Div.
U.S. Ceramic Tile



III A 2 a. Aluminas

'Diamonite' P-3459

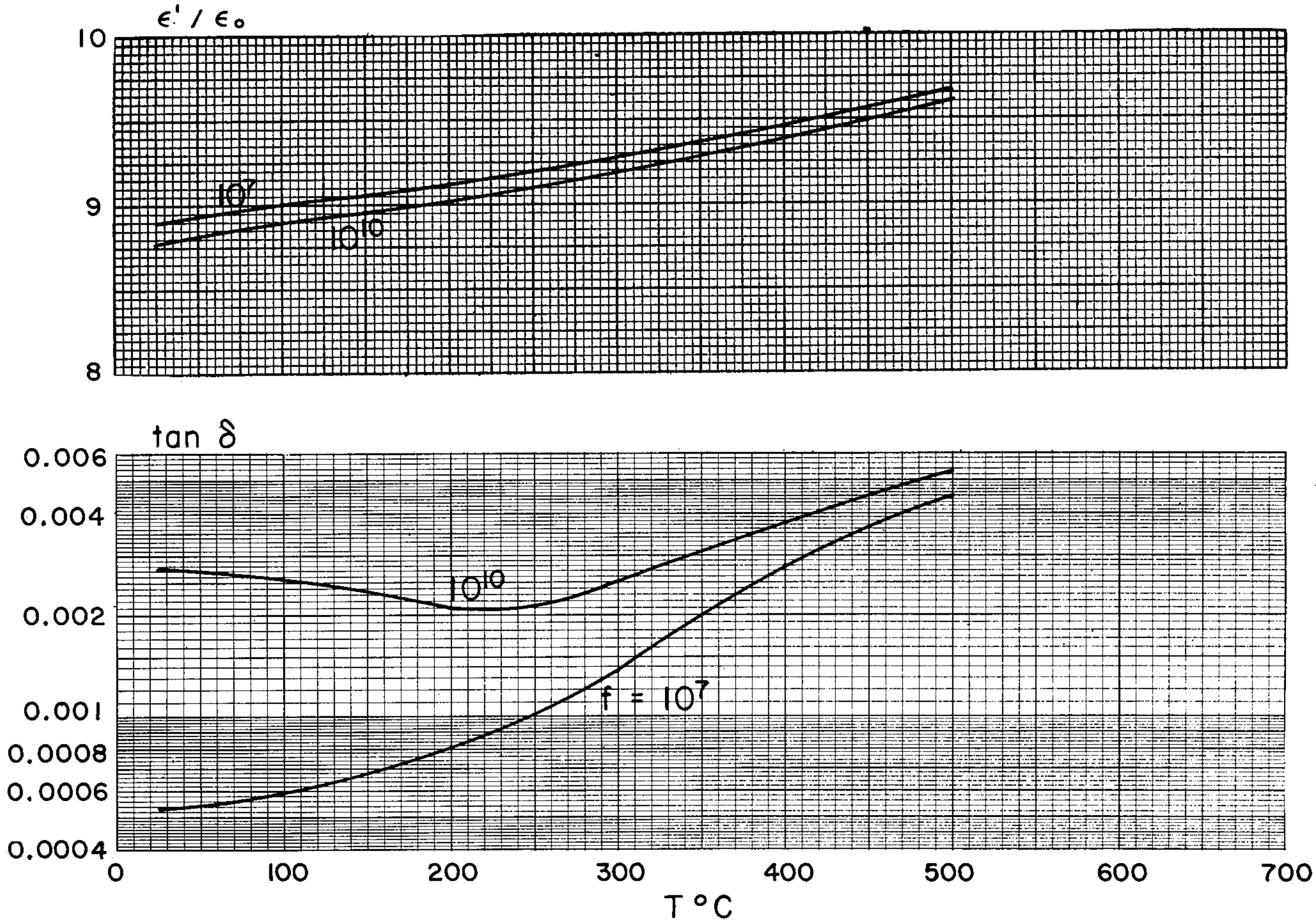
Diamonite Products Div.
U. S. Ceramic Tile



III A 2 a. Aluminas

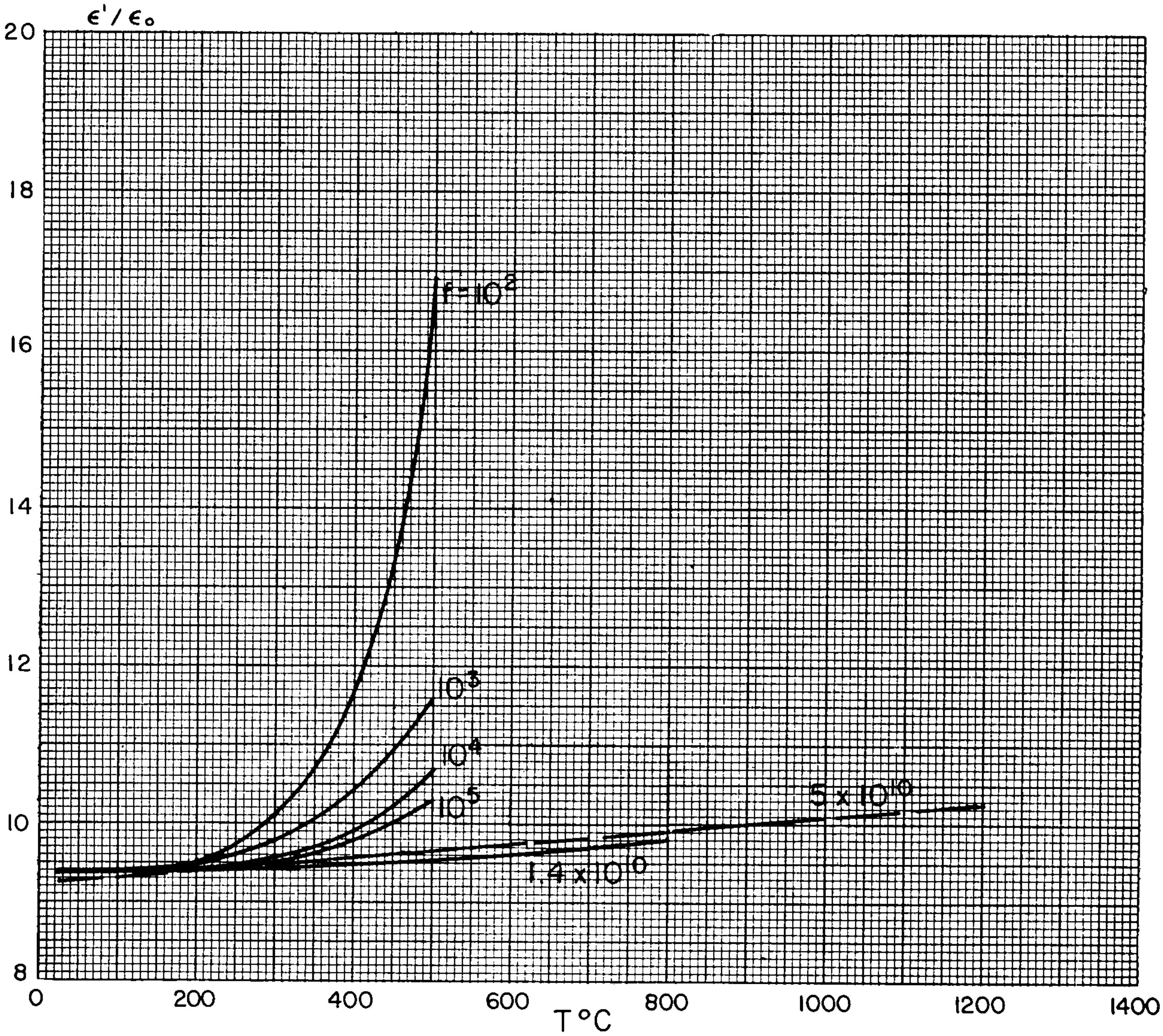
"Diamonite" P-3530-40

Diamonite Products Div.
U.S. Ceramic Tile



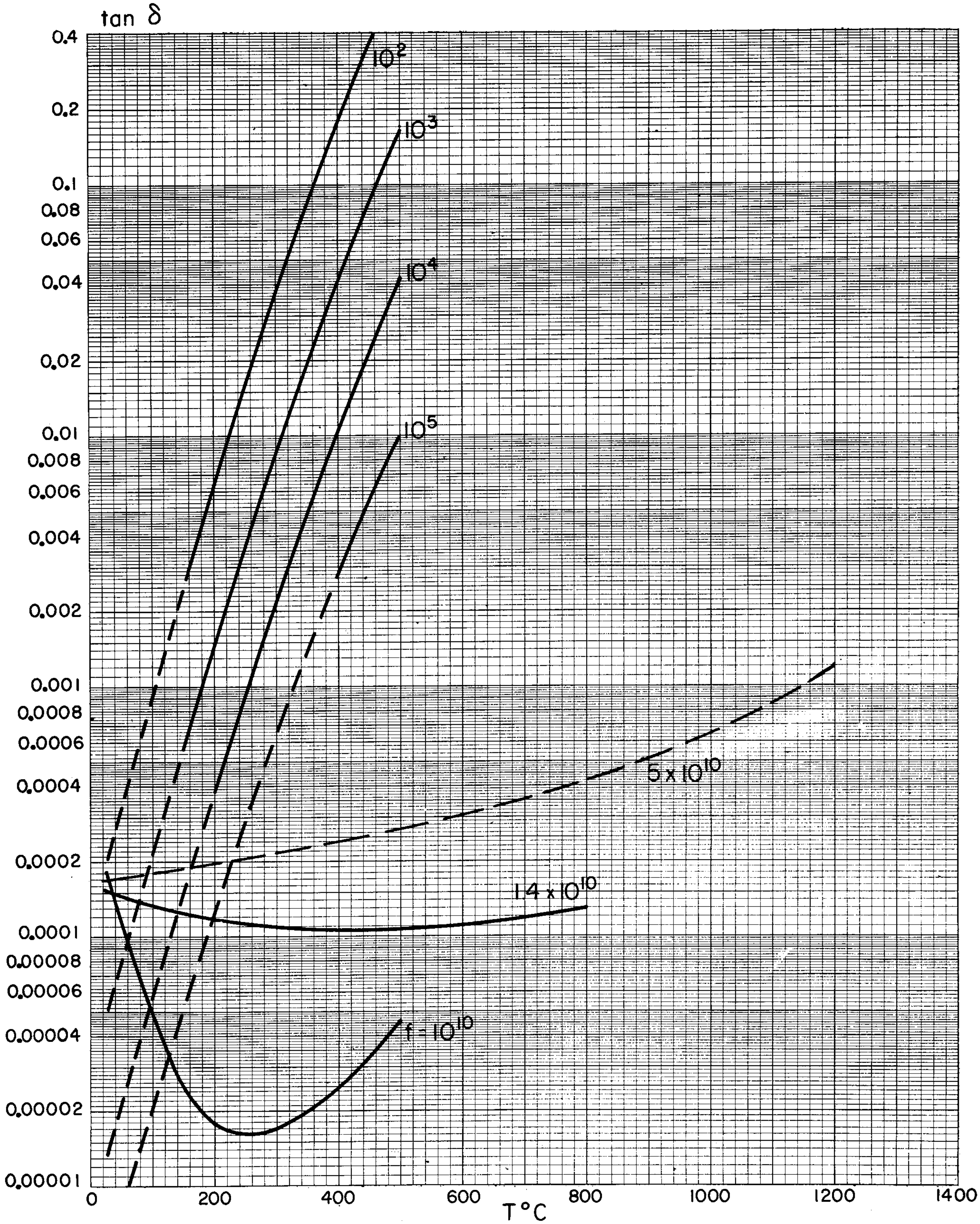
III A 2 a. Aluminas

Alumina (high purity) Kearfott



III A 2 a. Aluminas

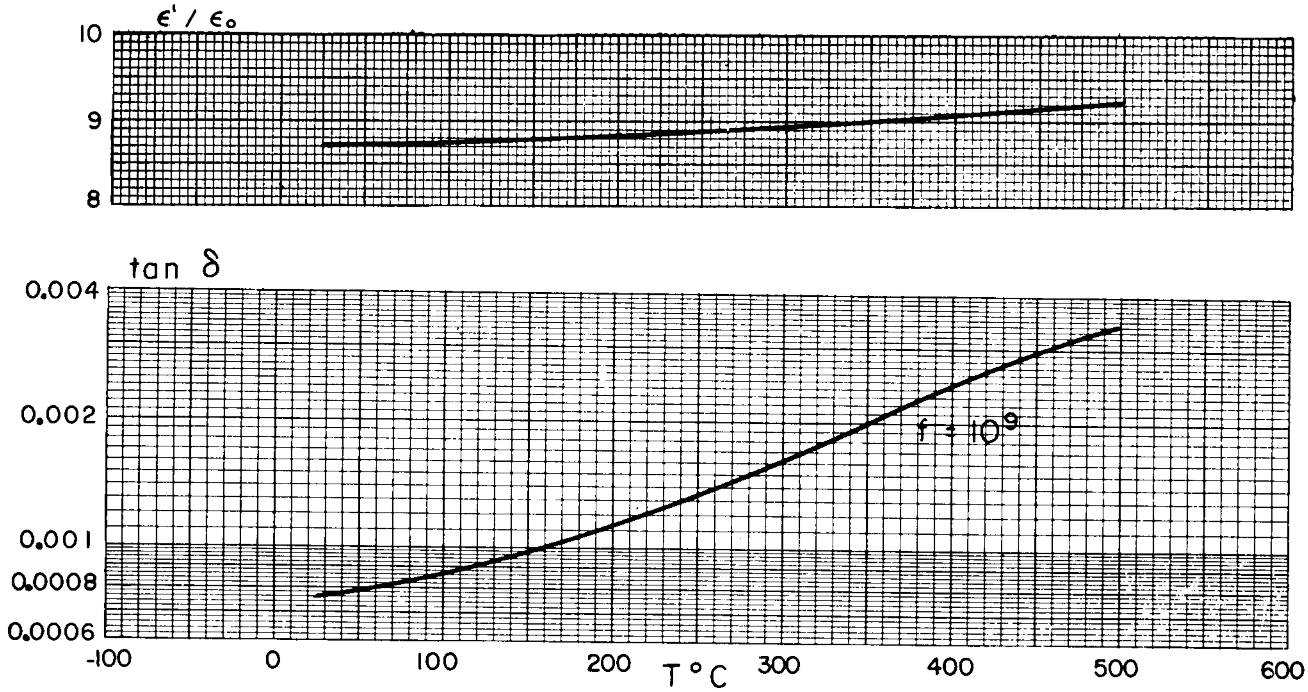
Alumina (high purity) Kearfott



III A 2 a. Aluminas

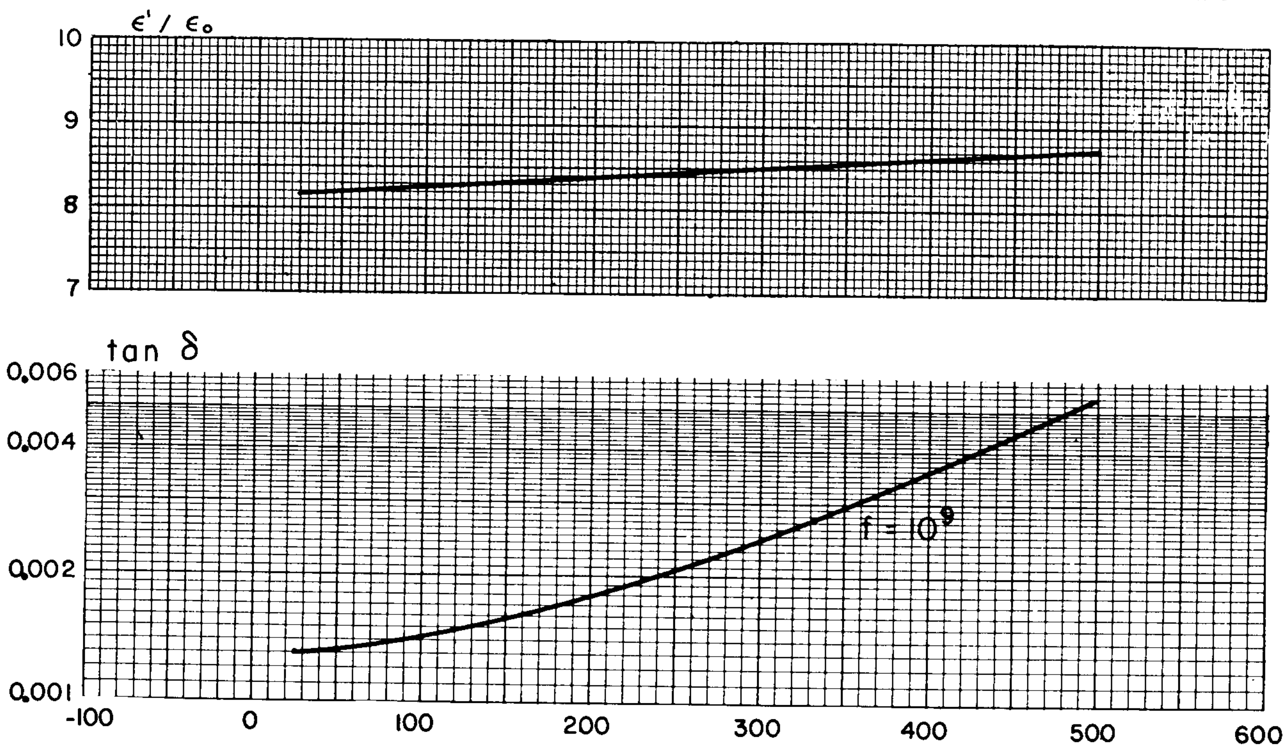
Frenchtown 4462

Frenchtown



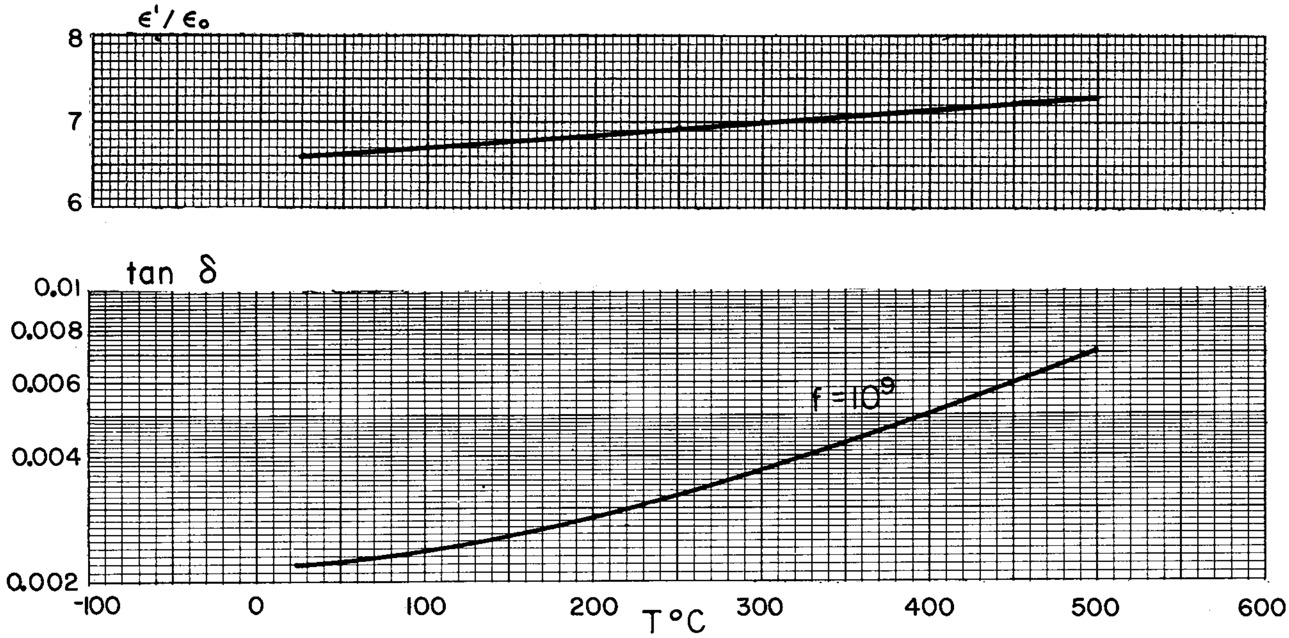
Frenchtown 6096

Frenchtown

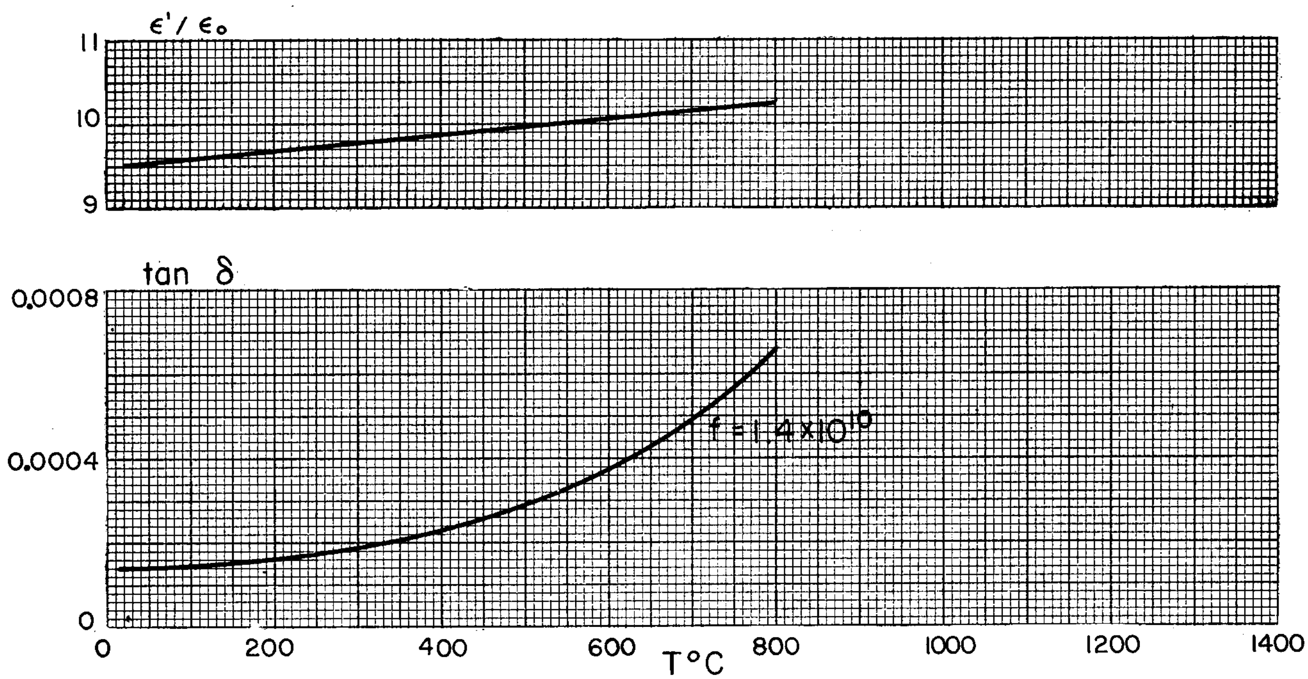


III A 2 a. Aluminas

Frenchtown 7873 Frenchtown



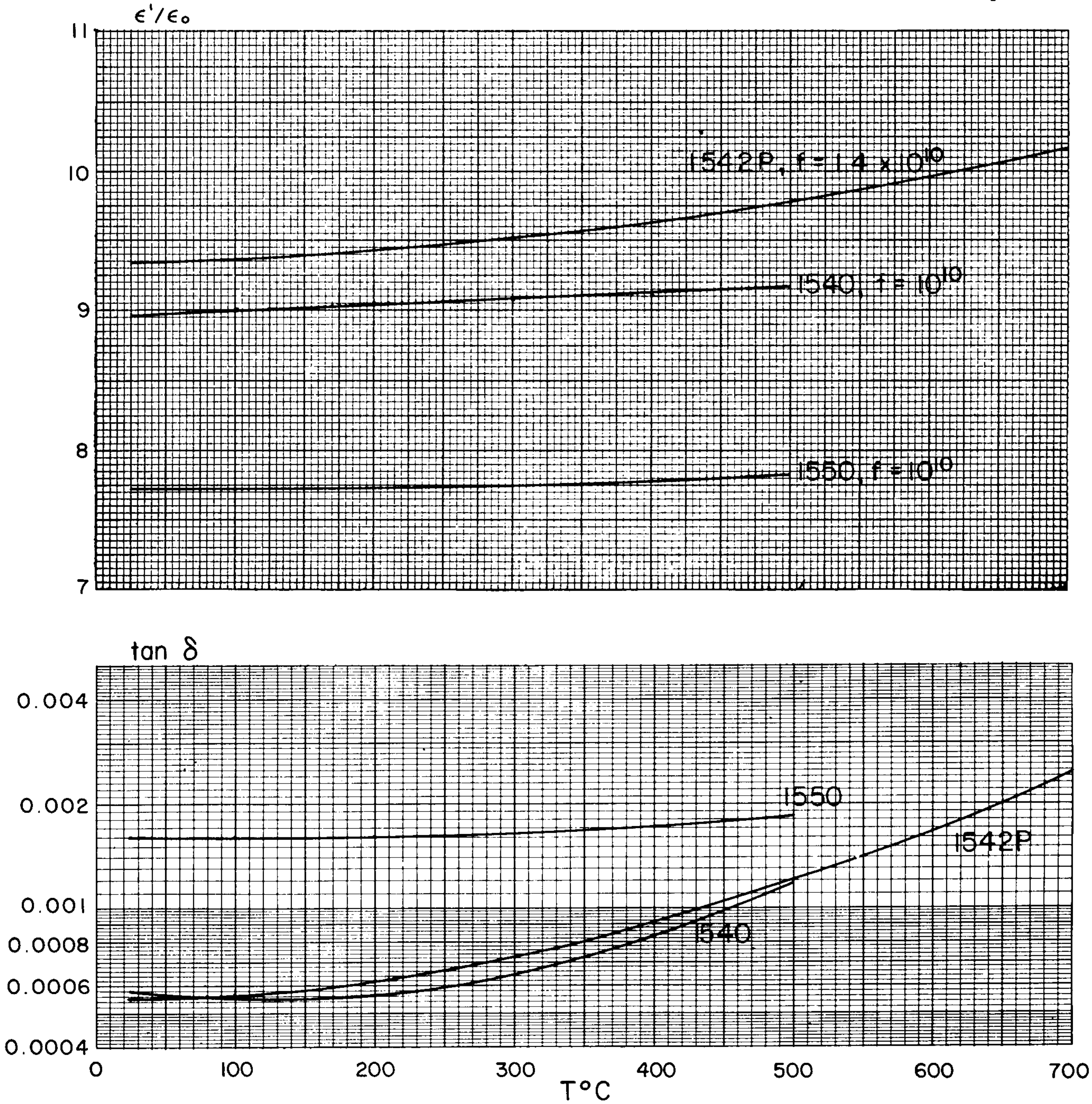
Alumina 7X Norton



III A 2 a. Aluminas

Stupakoff 1540, 1542P, and 1550

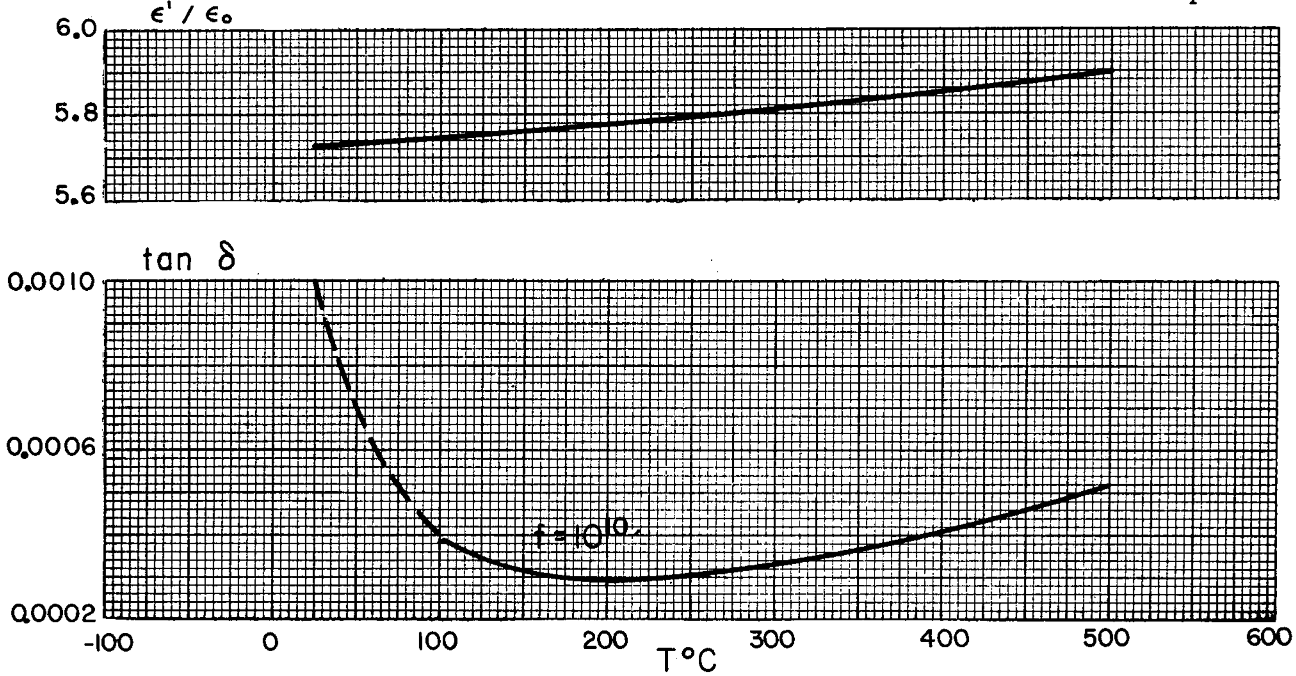
Stupakoff



III A 2 a. Aluminas

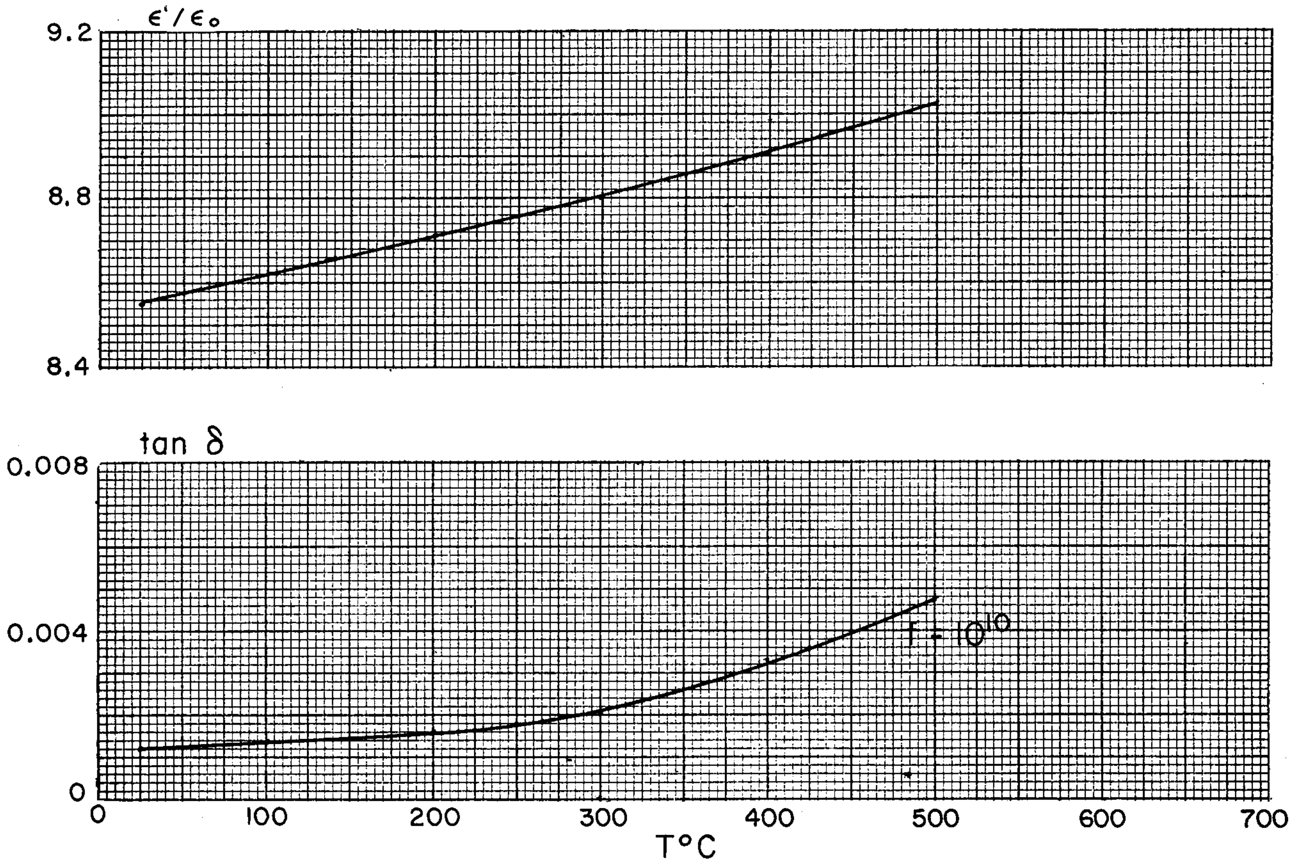
Stupakoff 1510

Stupakoff



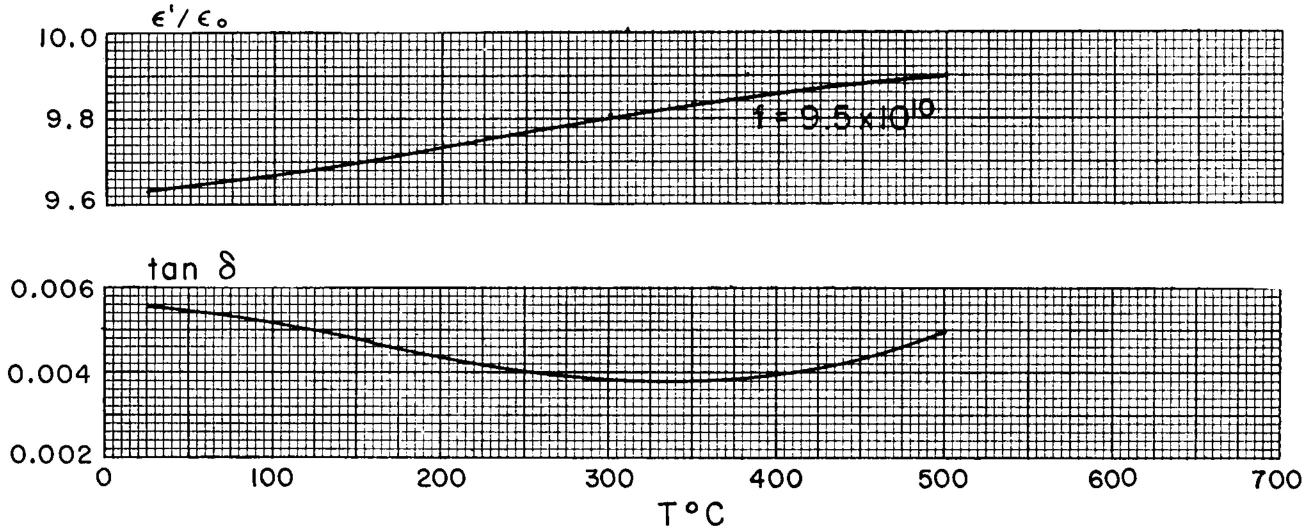
"Alite" AP 312

U.S. Stoneware



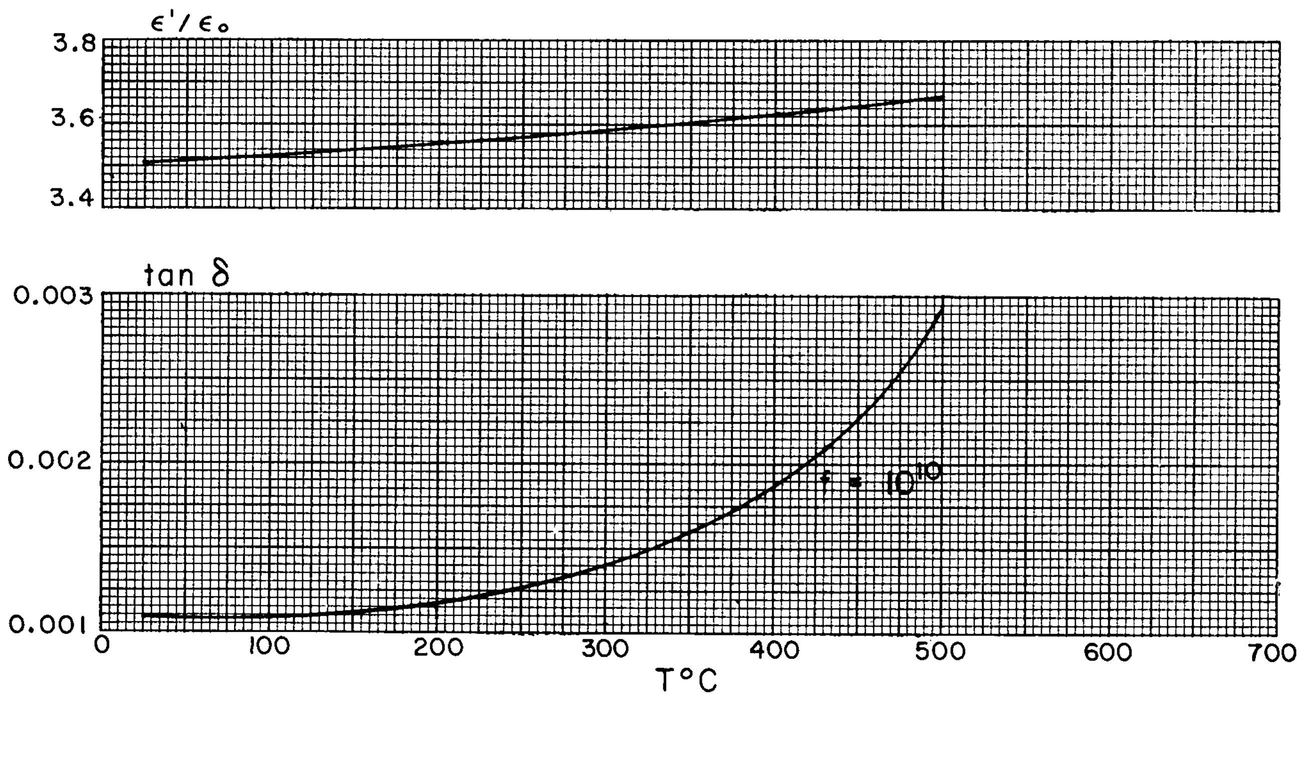
III A 2 a. Aluminas

"Wesgo" AL-300 Western Gold and Platinum



III A 2 b. Beryllias

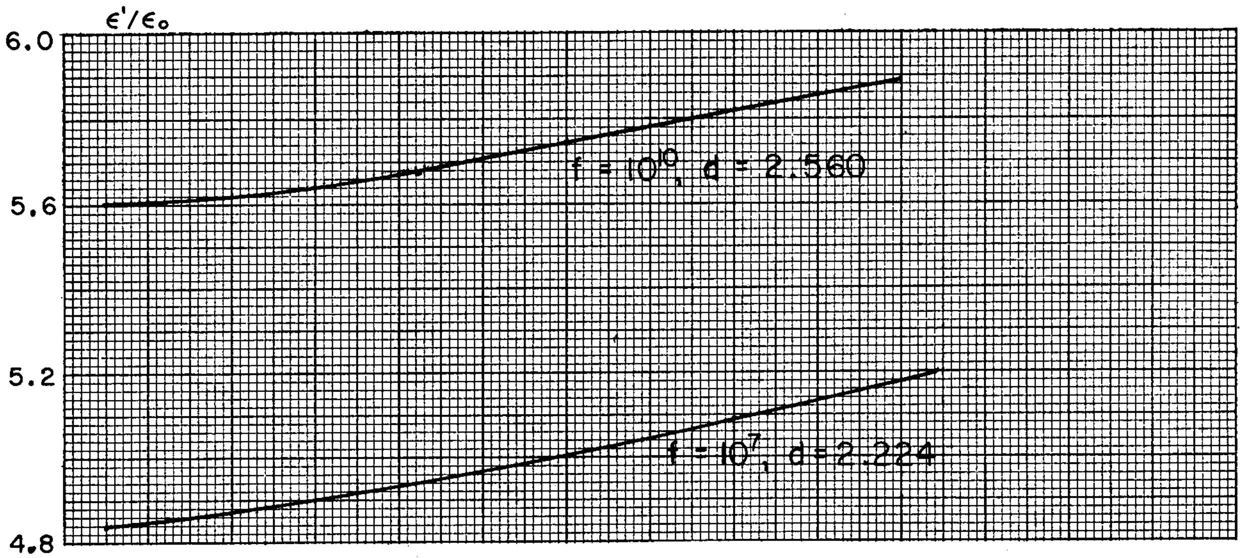
Beryllium oxide, crucible grade Beryllium Corp.

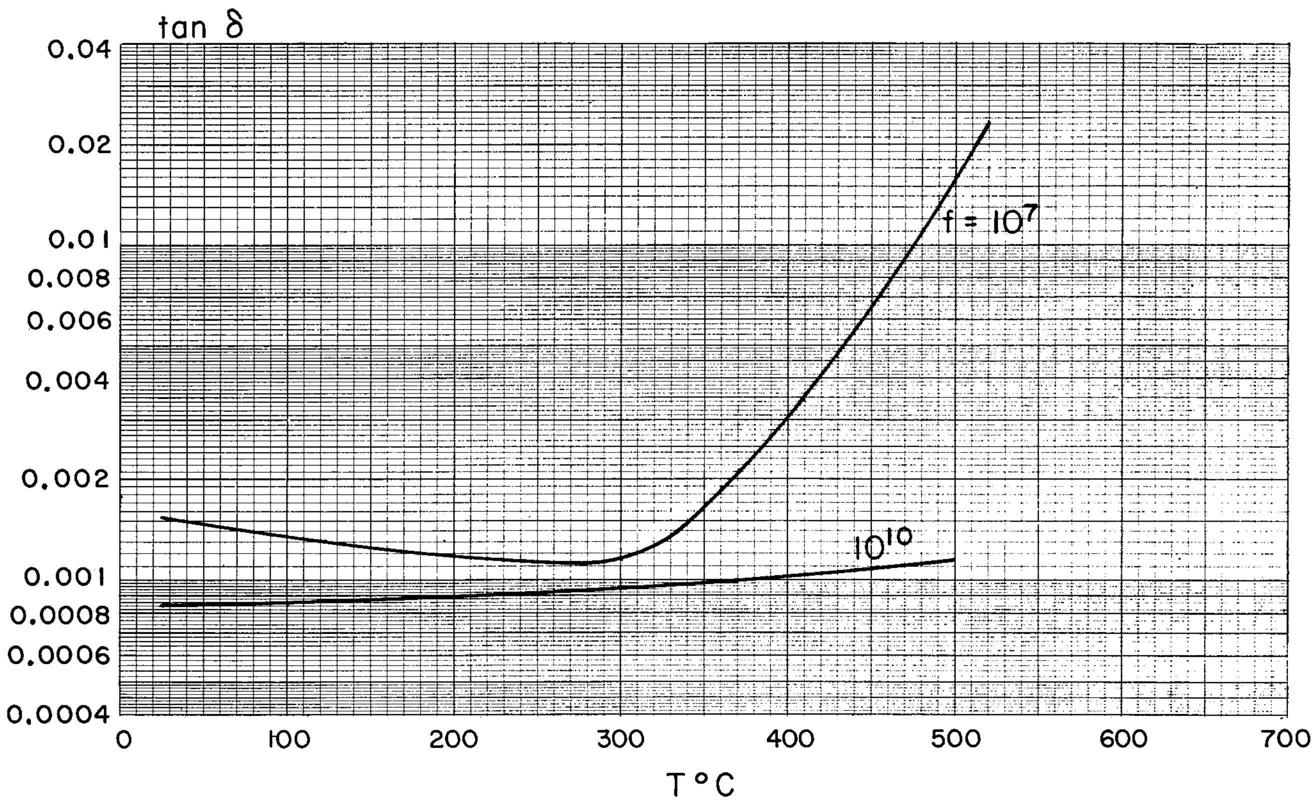


III A 2 b. Beryllias

Beryllium oxide, hot pressed

Beryllium Corp.

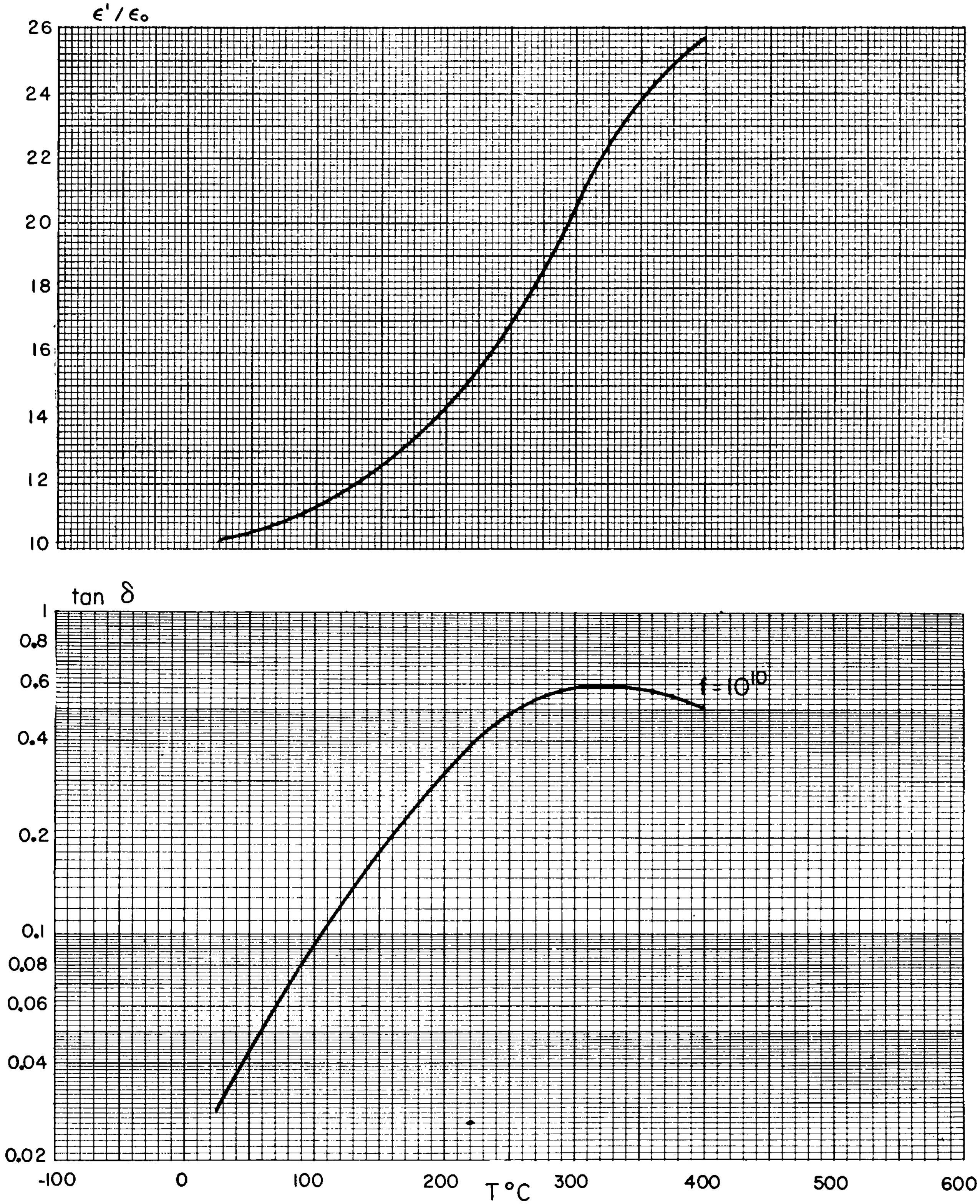




III A 2 c. Ferrites

Magnesium Manganite

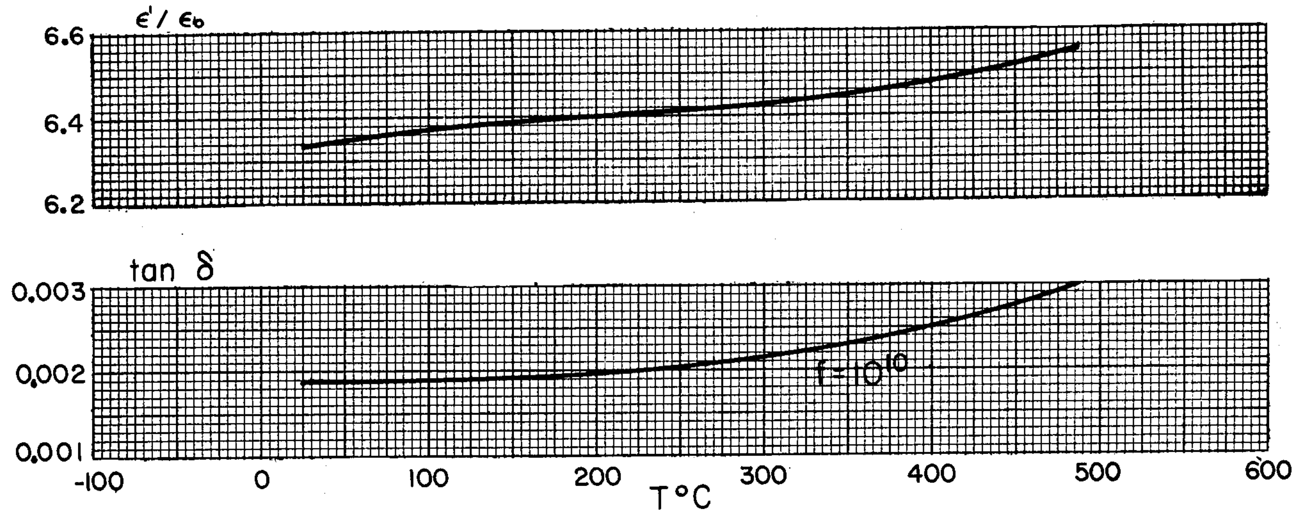
General Ceramics



III A 2 d. Steatite

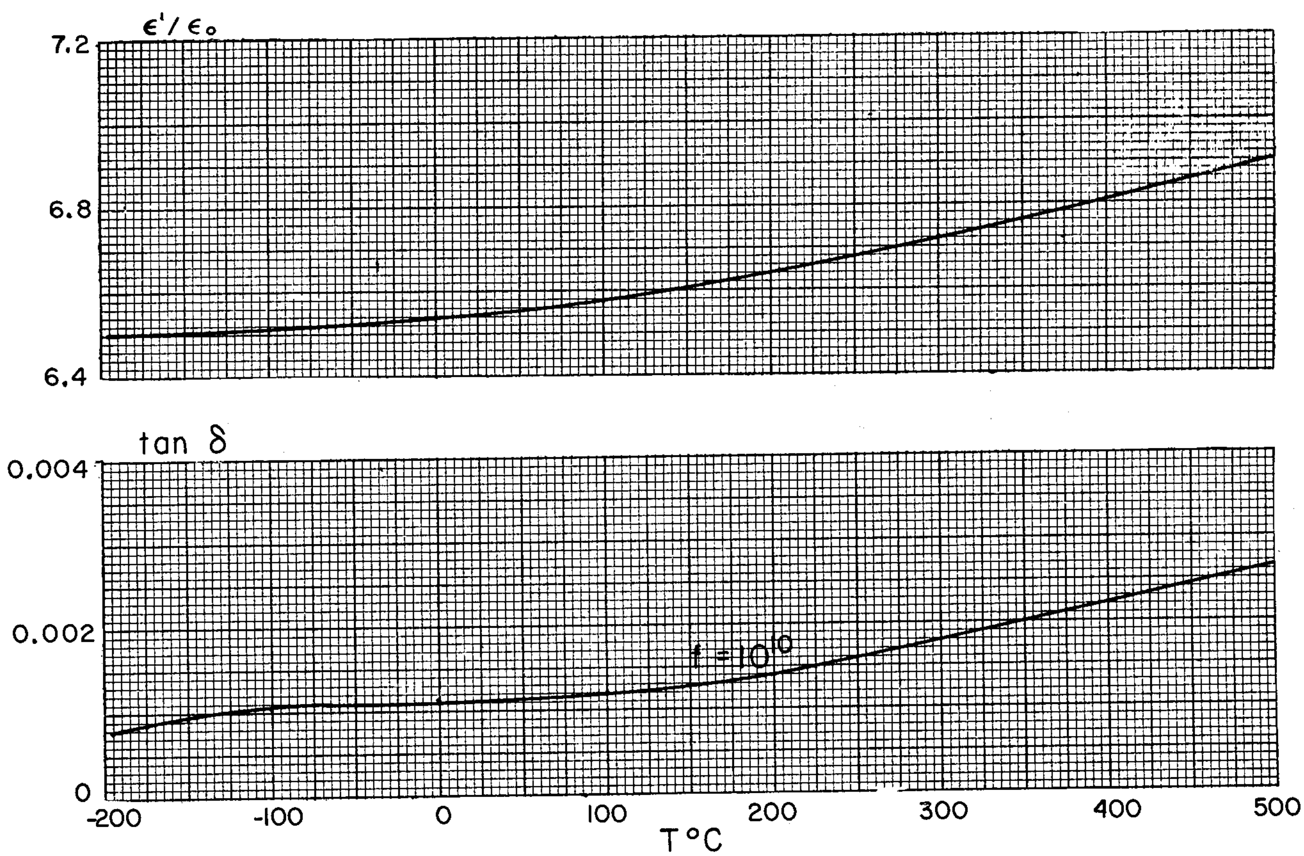
Ceramic BN 3054

General Ceramics

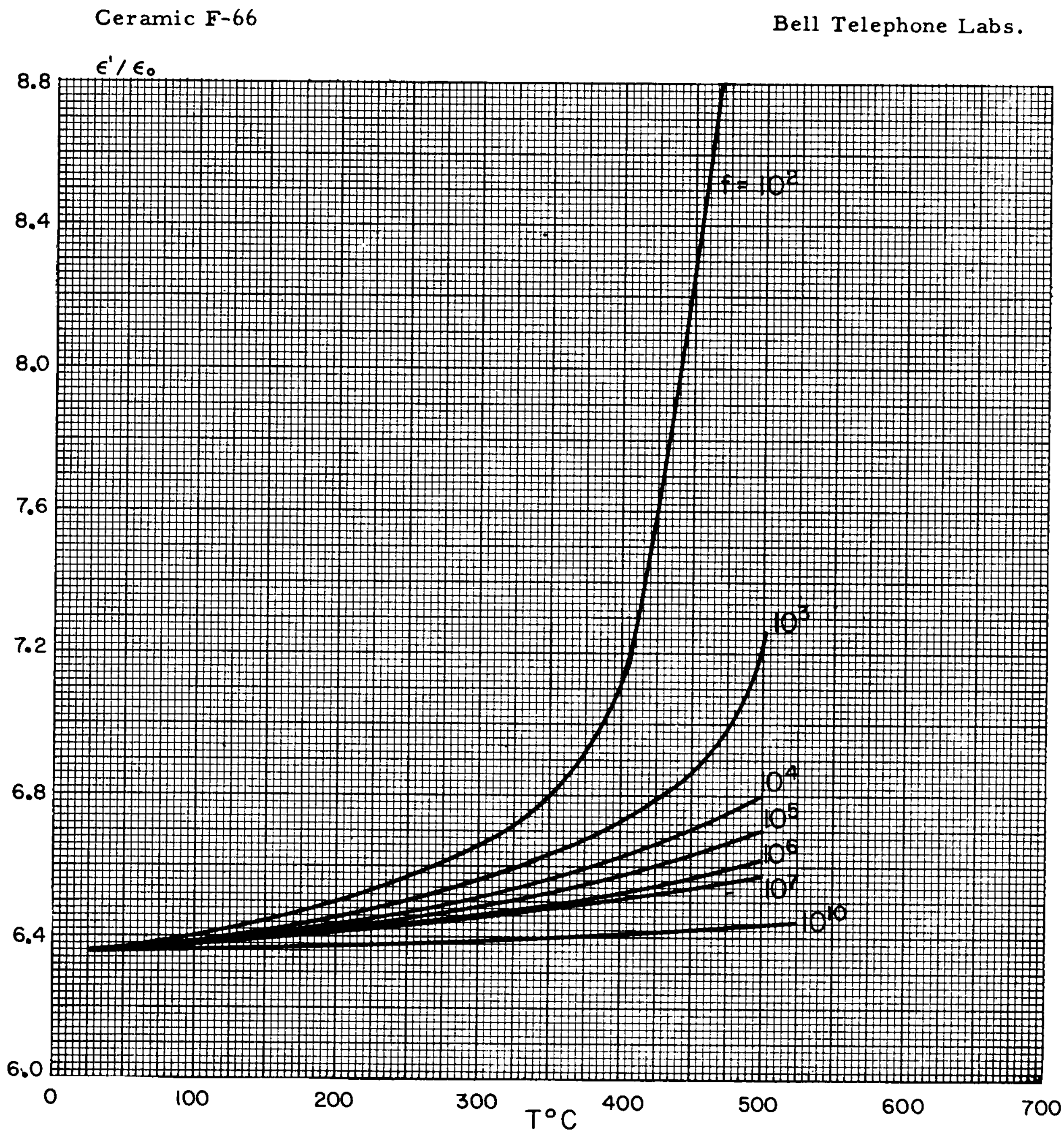


Steatite body 7292

General Ceramics



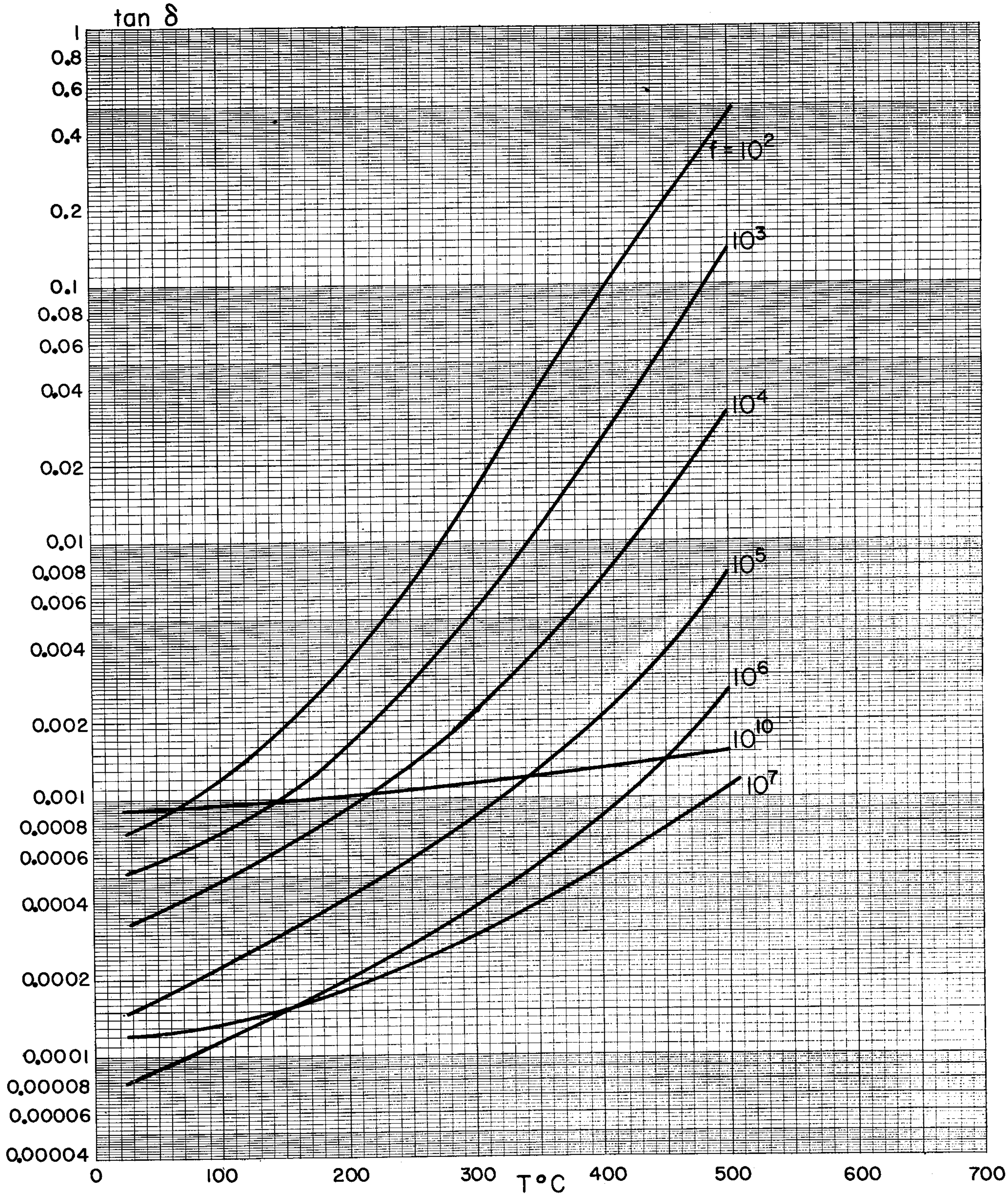
III A 2 d. Steatite



III A 2 d. Steatite

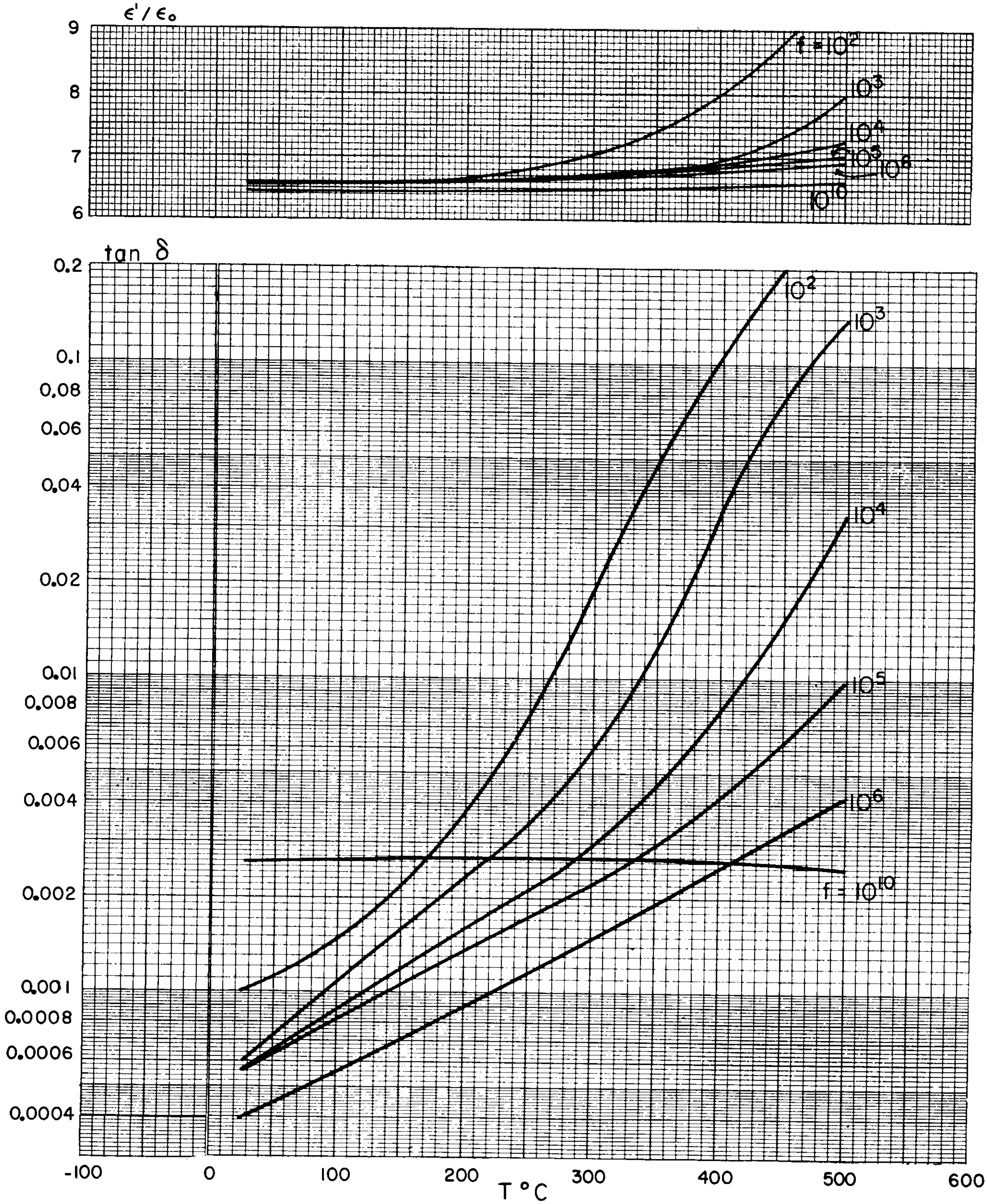
Ceramic F-66

Bell Telephone Labs.



III A 2 e. Wollastonite

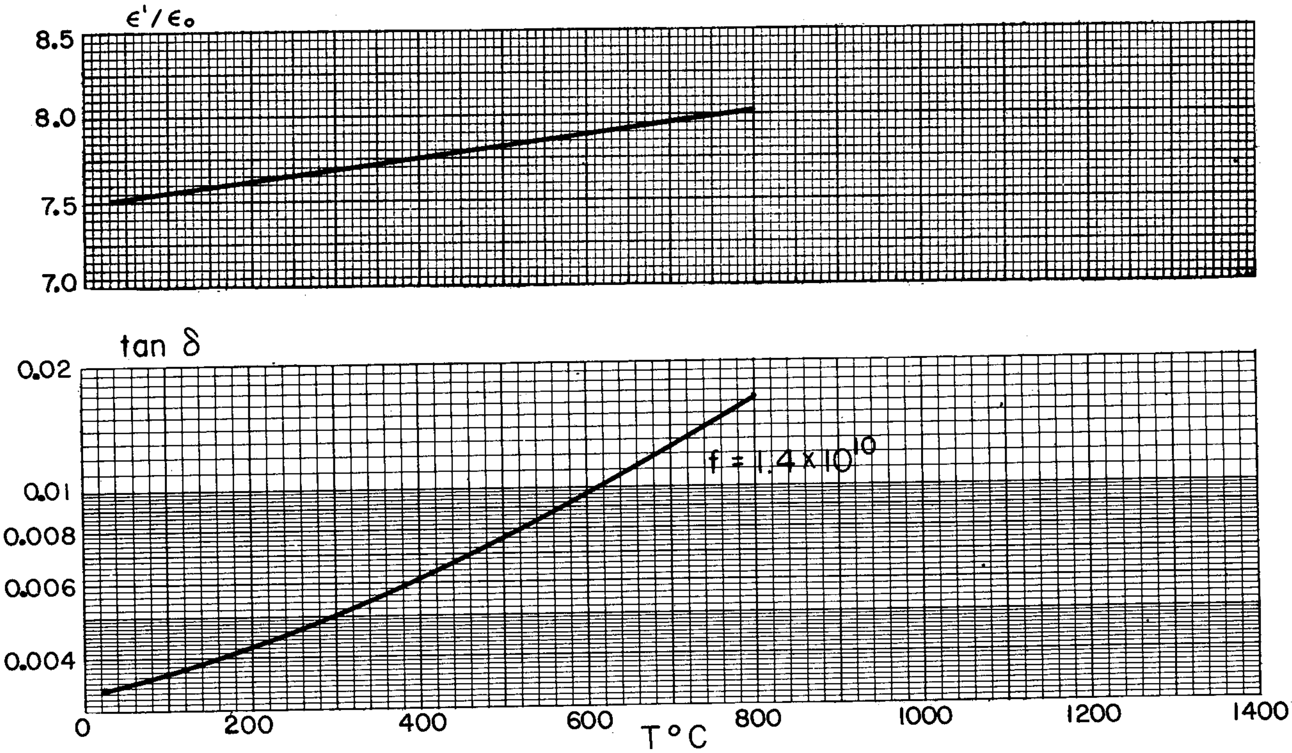
"AlSiMag" 577 American Lava



III A 2 f. Zircons

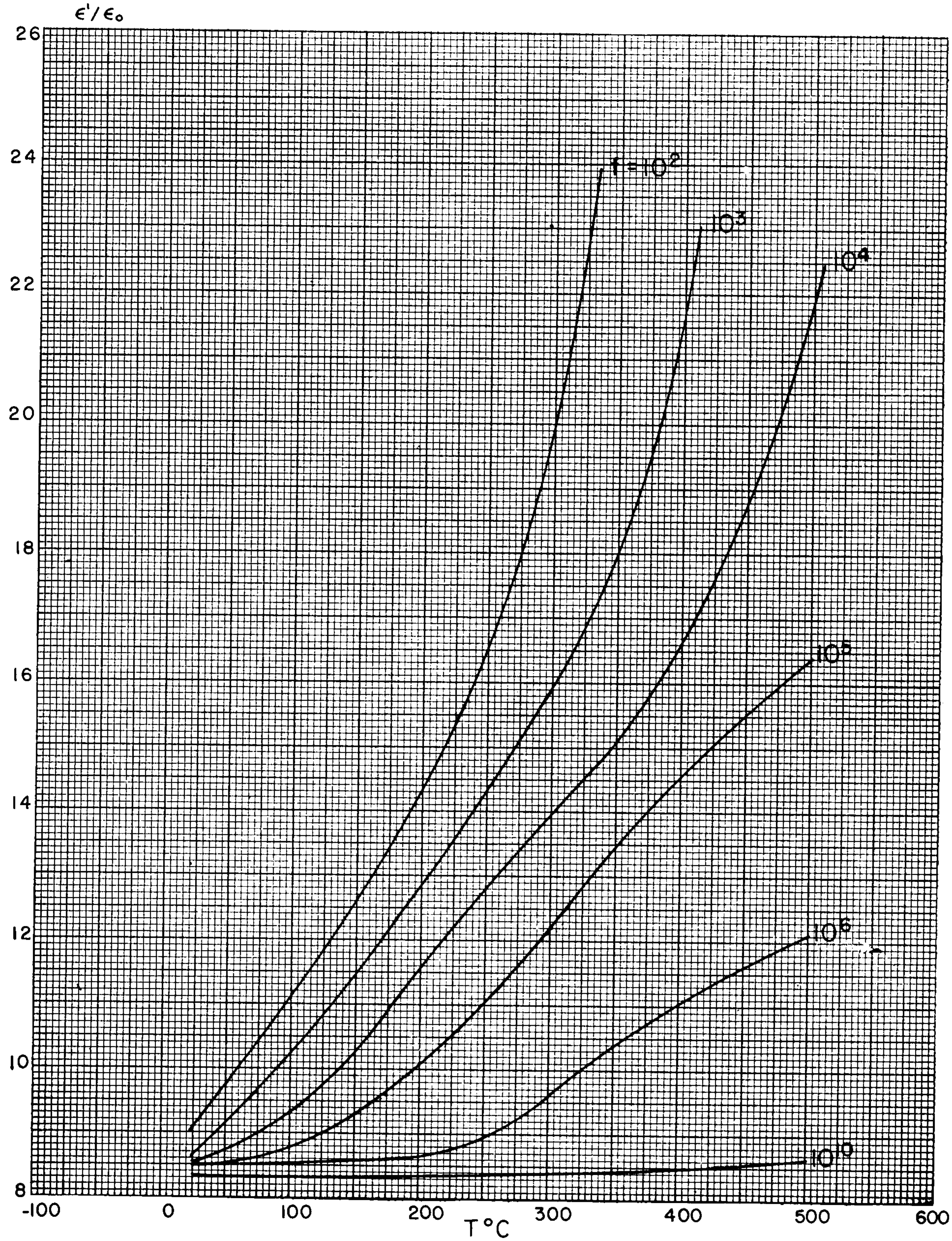
"AlSiMag" 475 (density 3.43 gm/cc)

American Lava



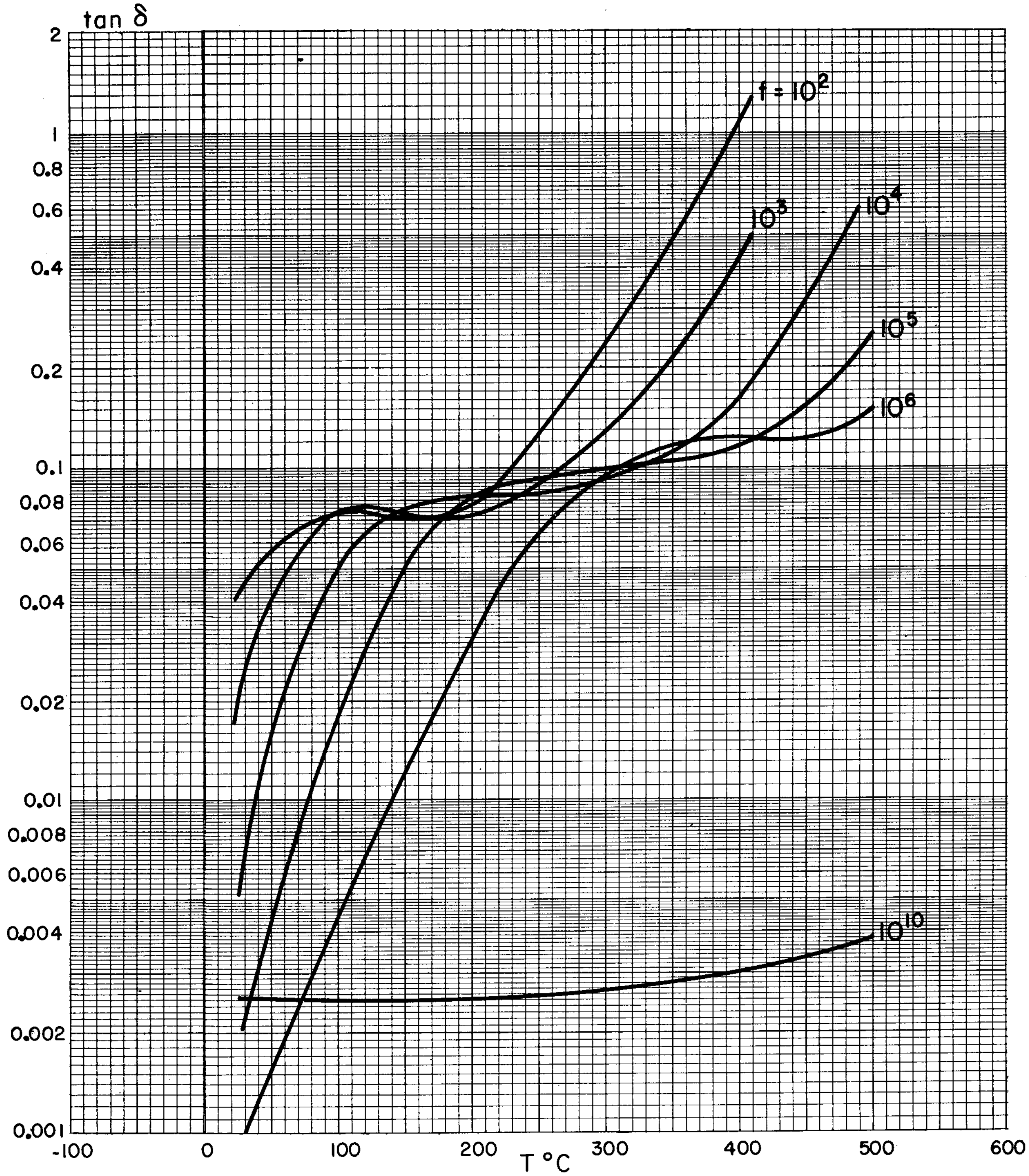
III A 2 f. Zircons

"AlSiMag" 475 (density 3.69 gm/cc) American Lava



III A 2 f. Zircons

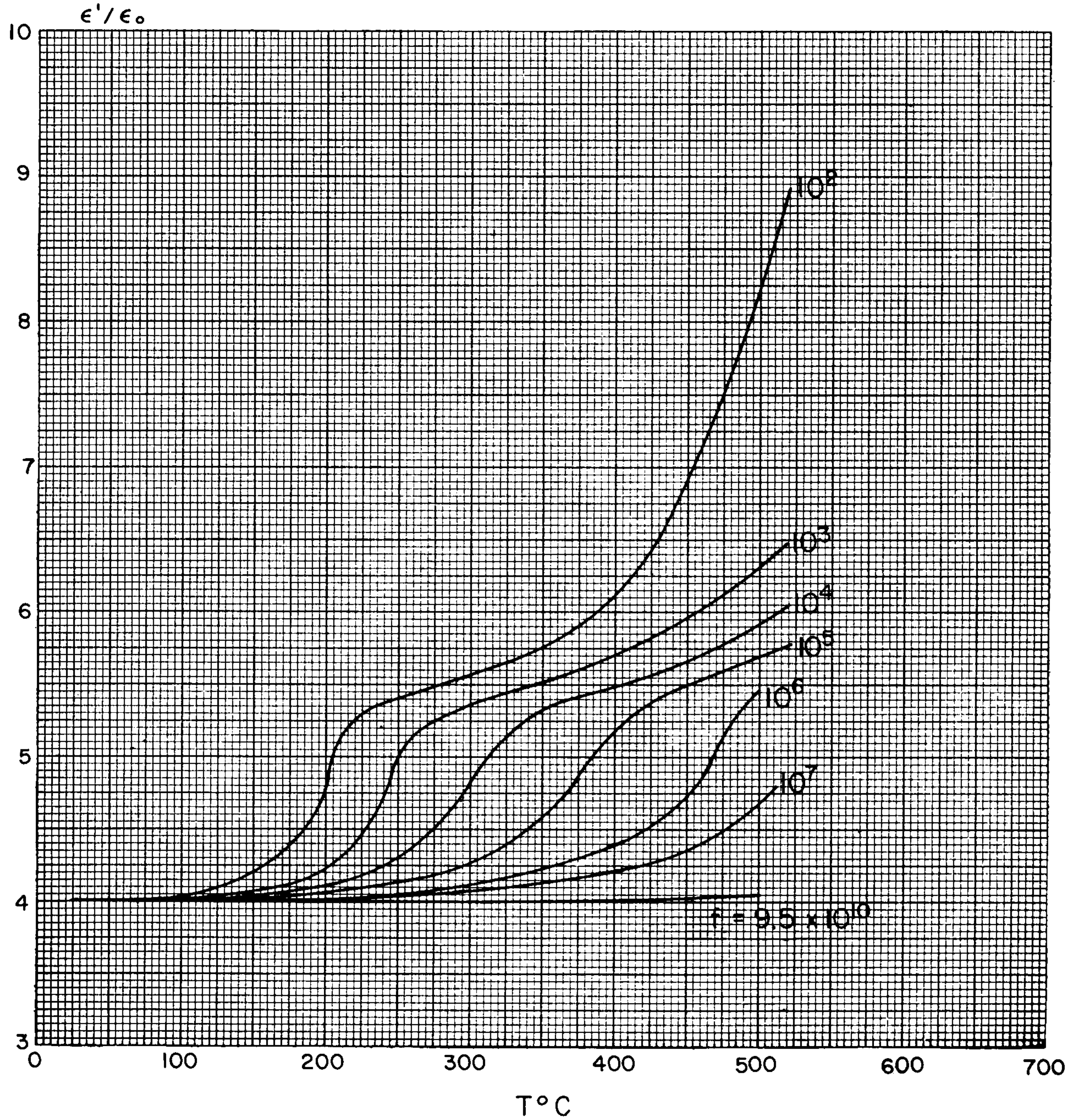
"AlSiMag" 475 (density 3.69 gm/cc) American Lava



III A 3. Glasses

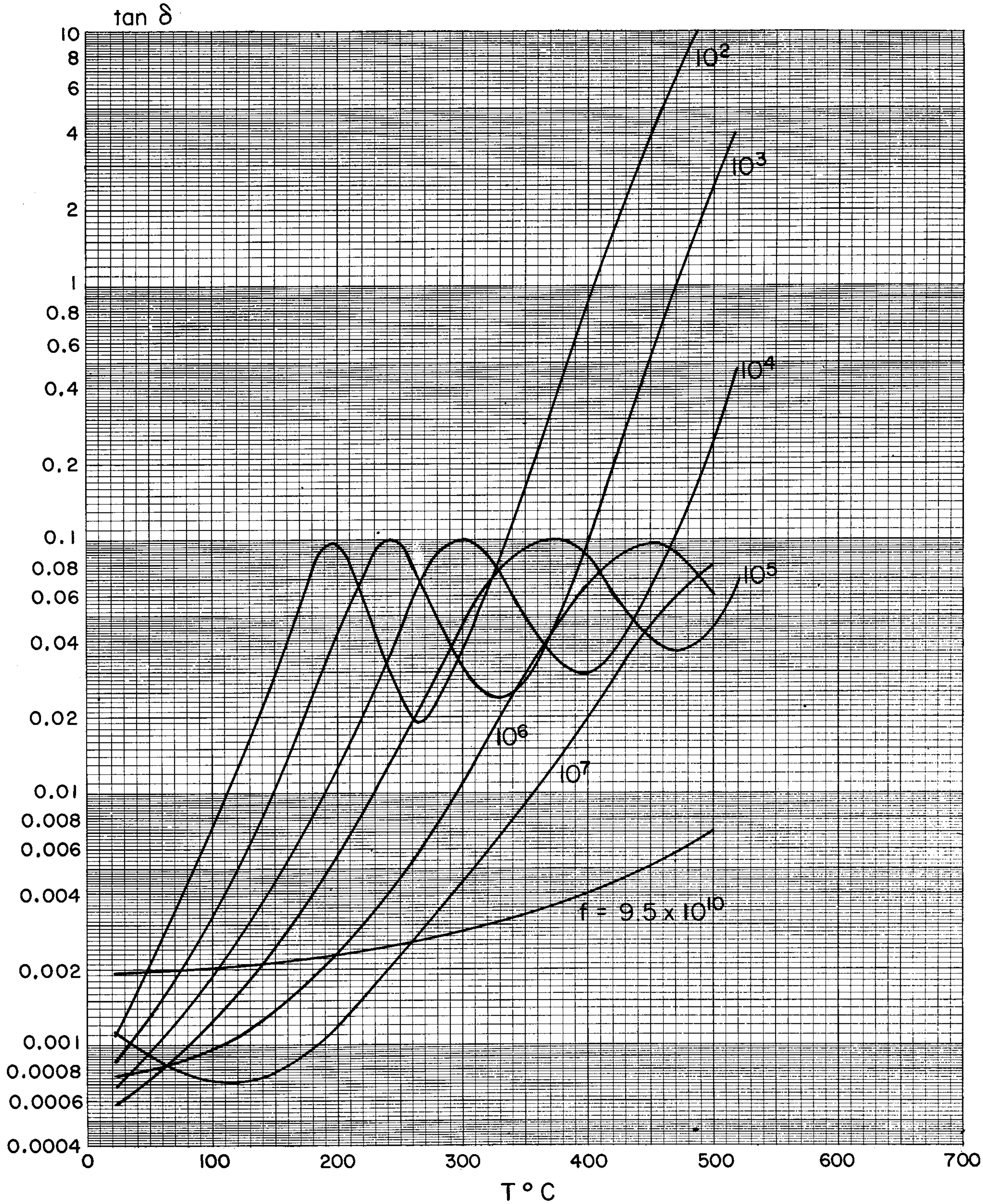
Corning glass 7070

Corning



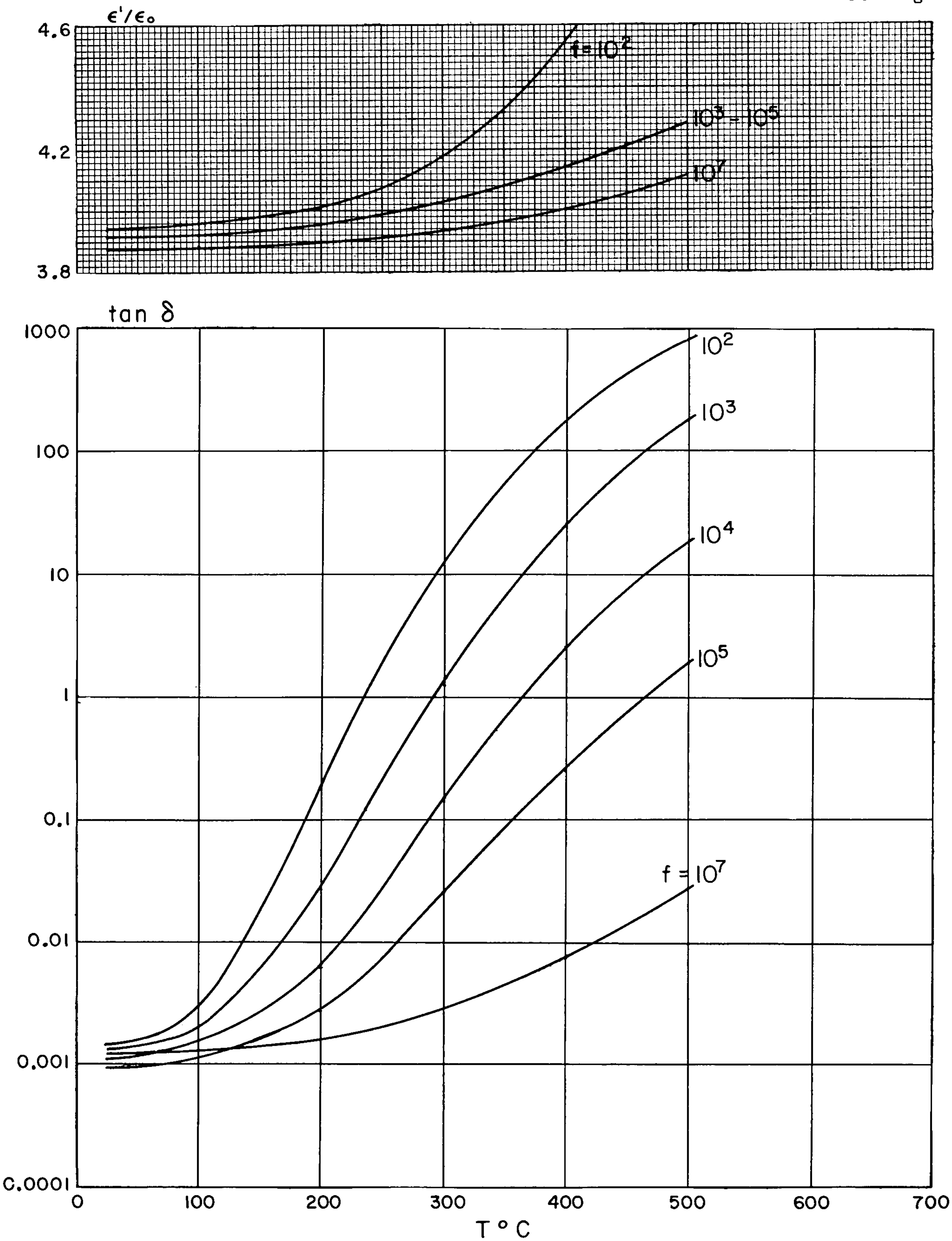
III A 3. Glasses

Corning glass 7070 | Corning



Corning 7900 glass (received 1942, measured 1957)

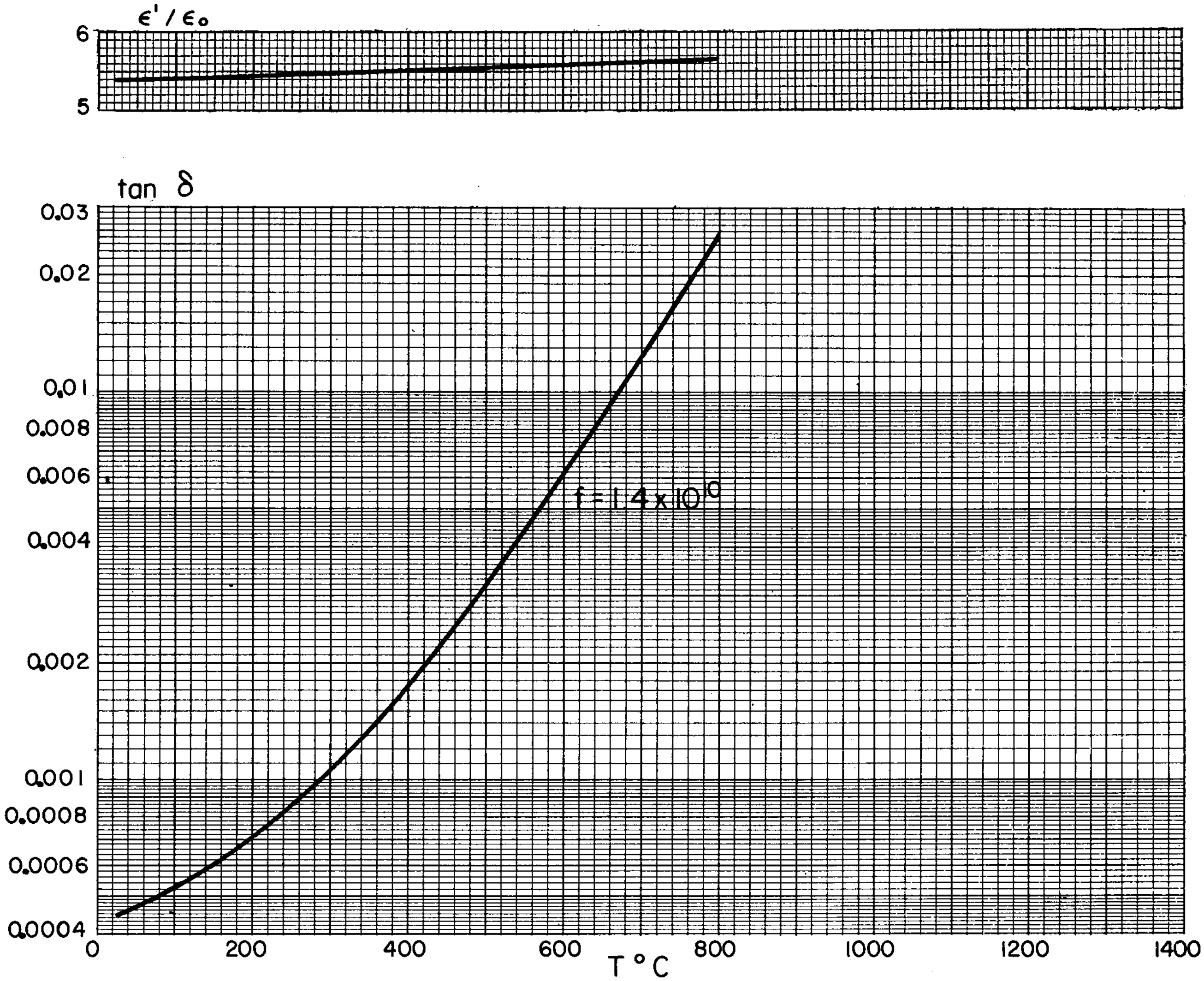
Corning



III A 3. Glasses

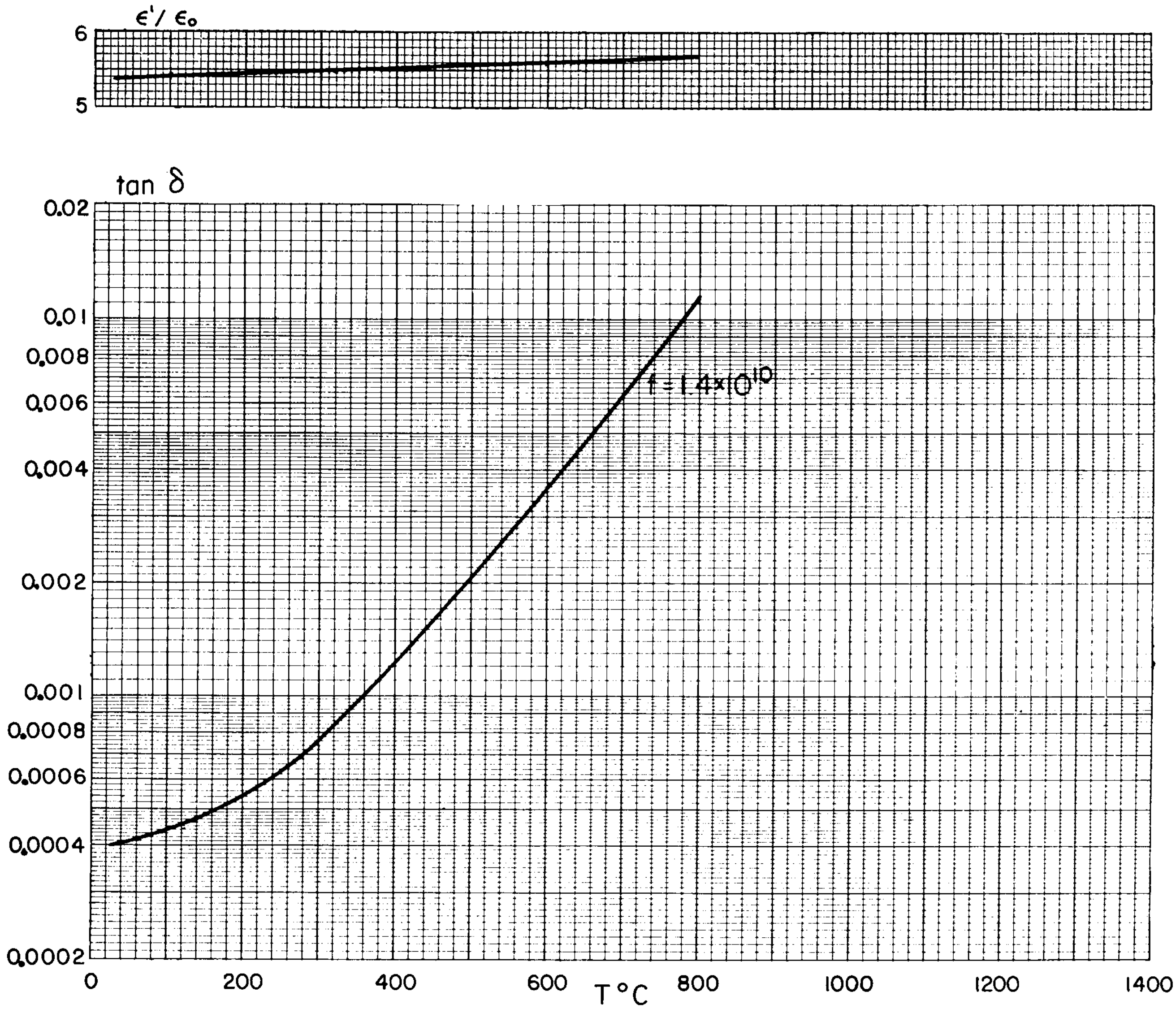
"Ceram" 61-1

Corning Glass



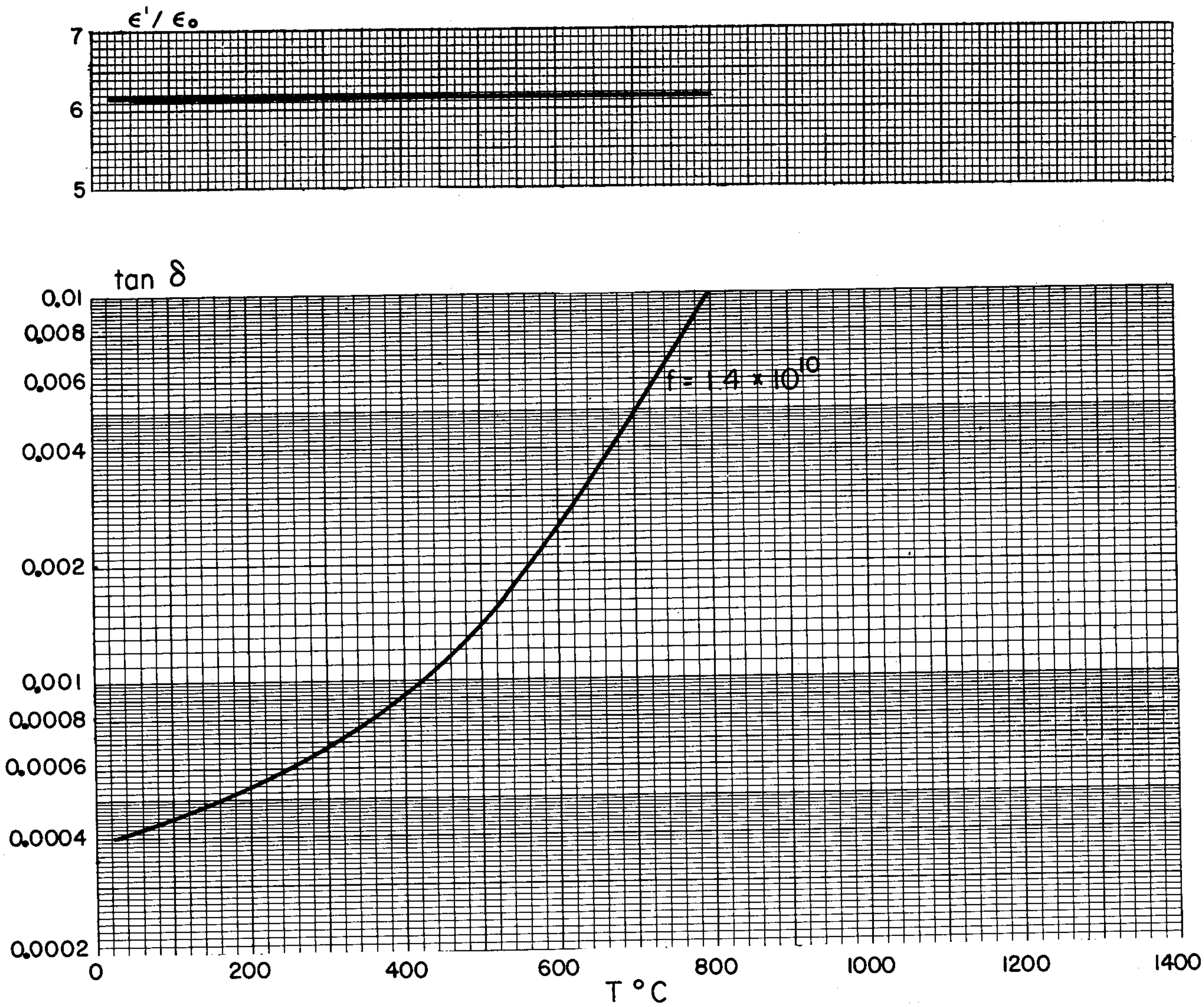
III A 3. Glasses

"Ceram" 61-2 Corning Glass



III A 3. Glasses

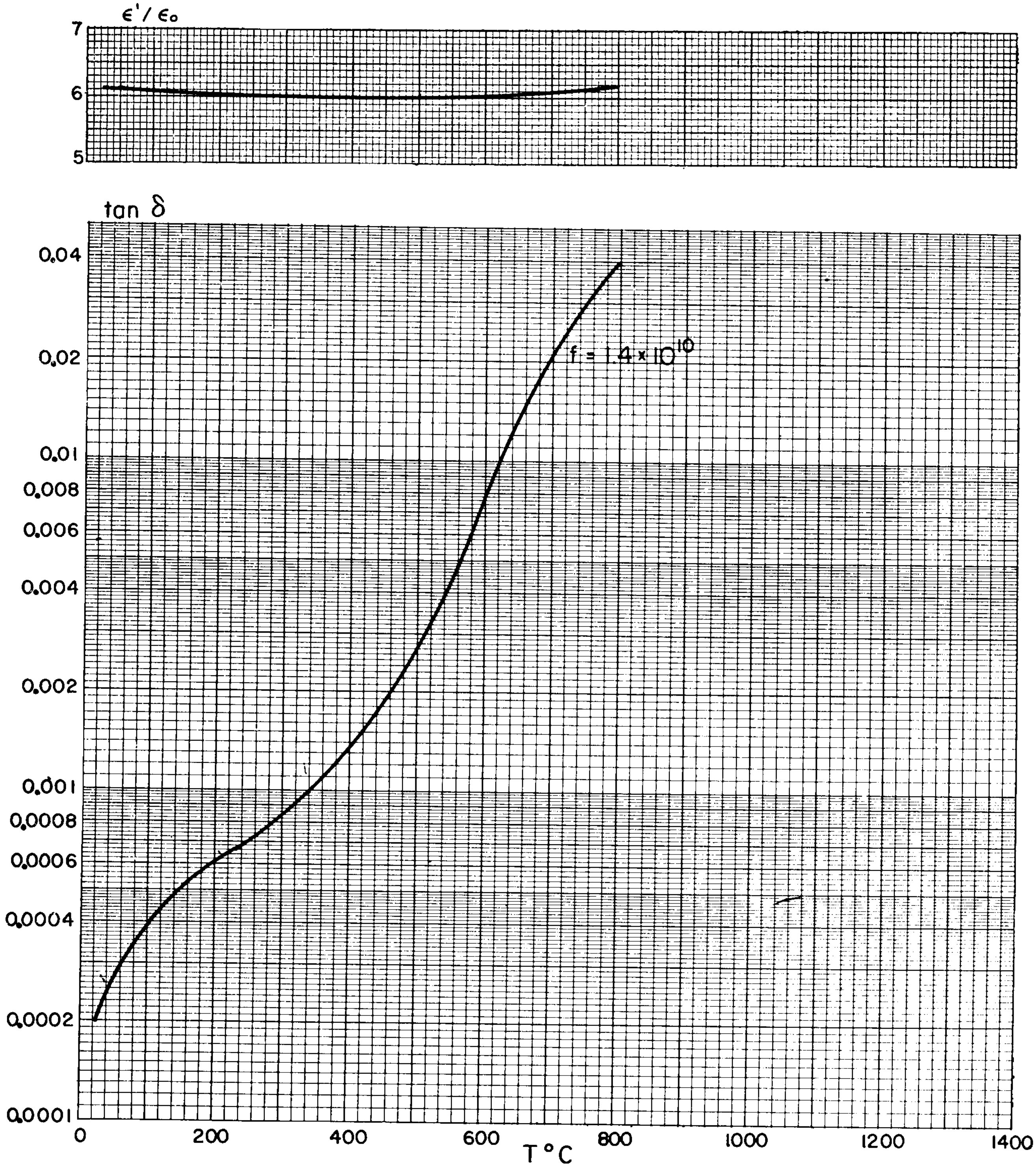
"Ceram" 61-3 Corning Glass



III A 3. Glasses

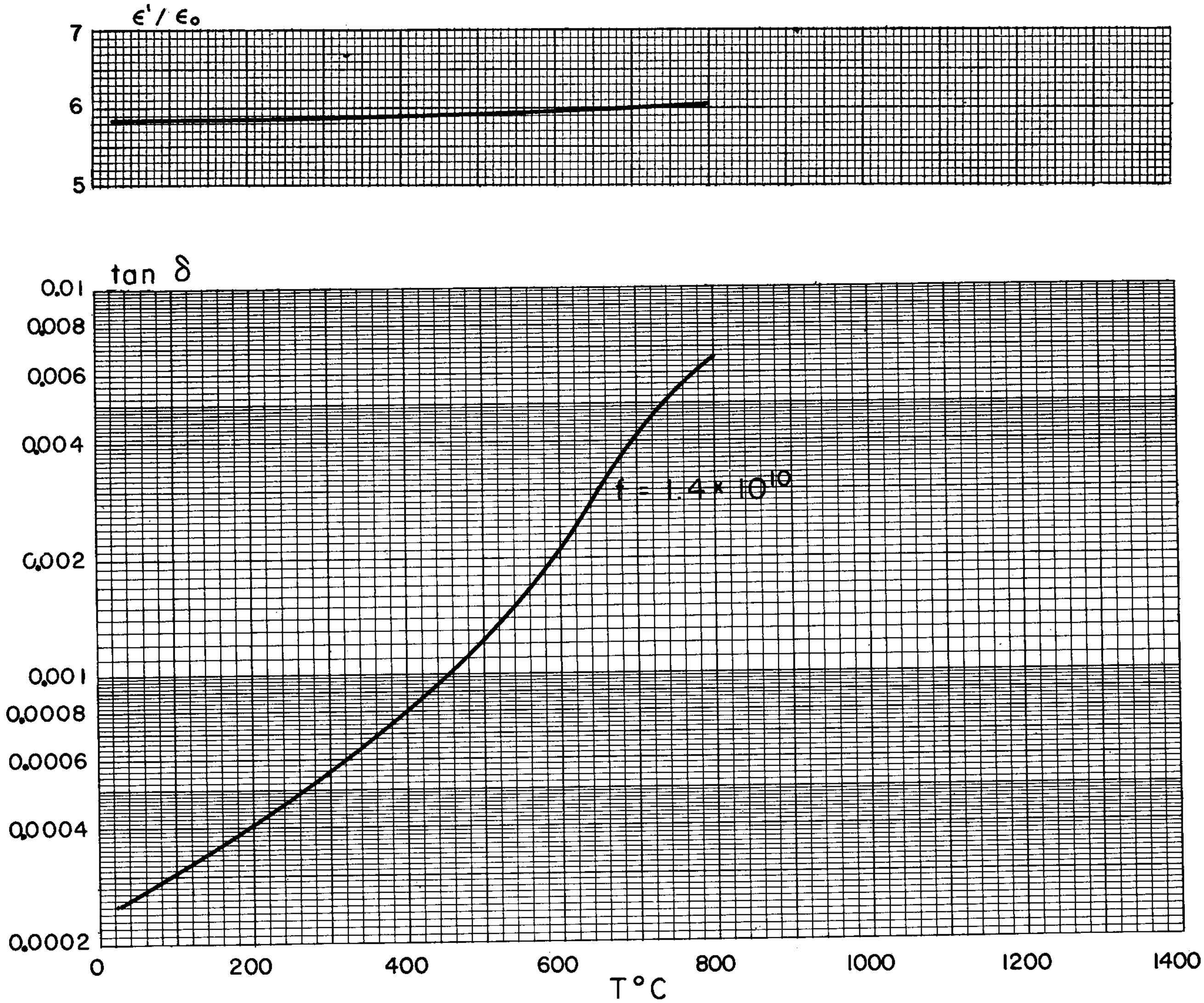
"Ceram" 61-4

Corning Glass



III A 3. Glasses

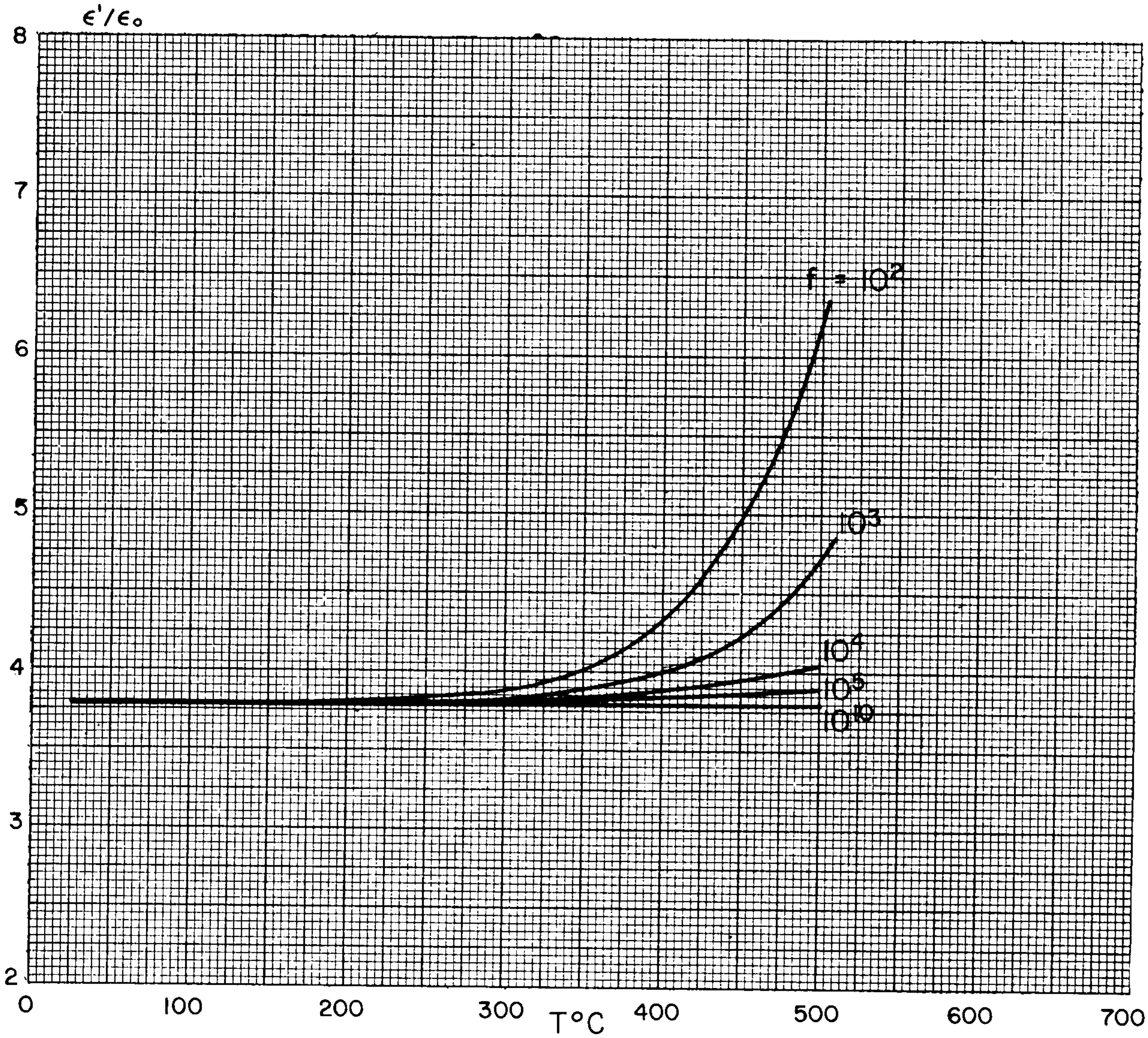
"Ceram" 61-5 | Corning Glass



III A 3. Glasses

Fused Silica 915 c

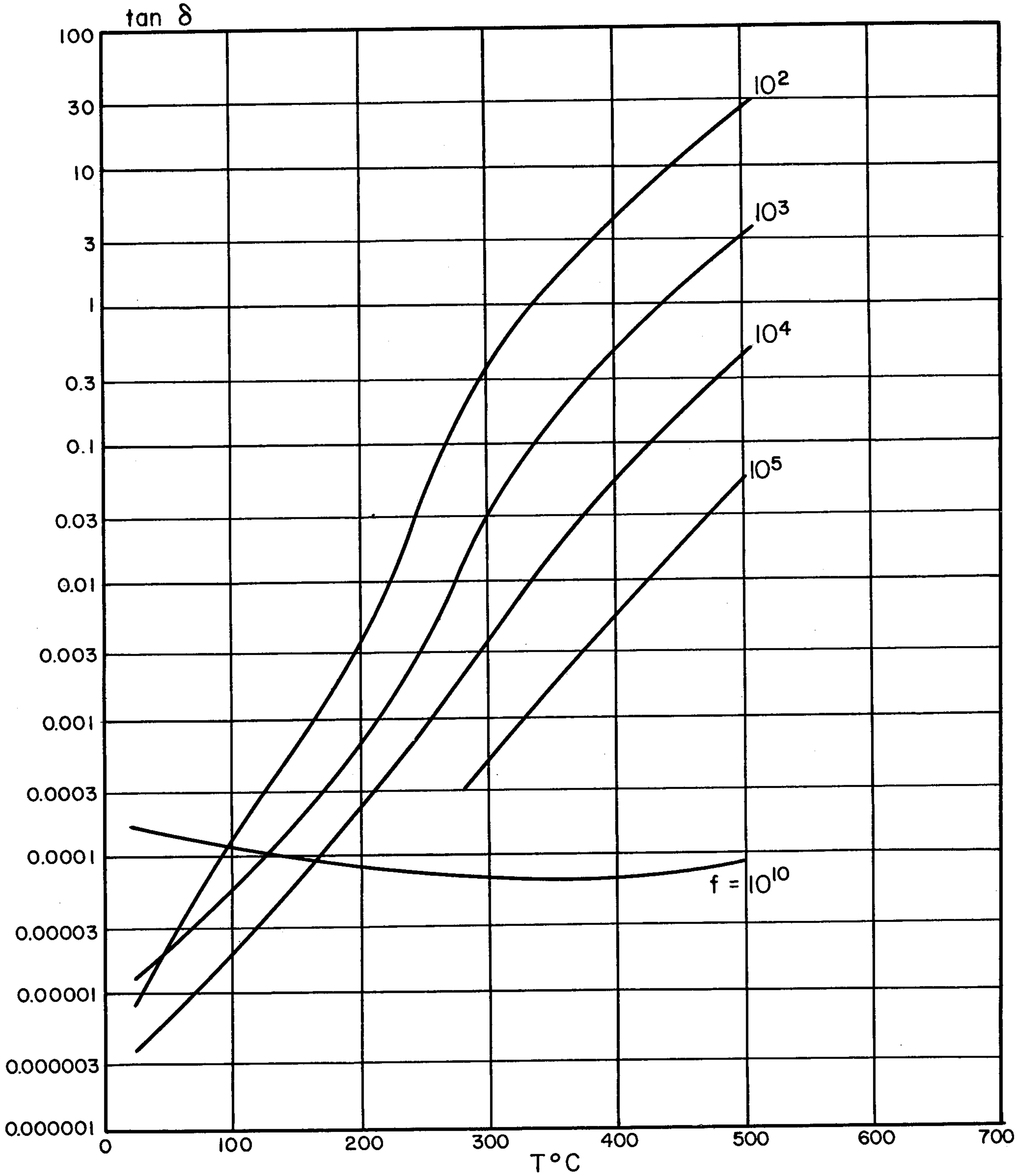
Corning



III A 3. Glasses

Fused Silica 915 c

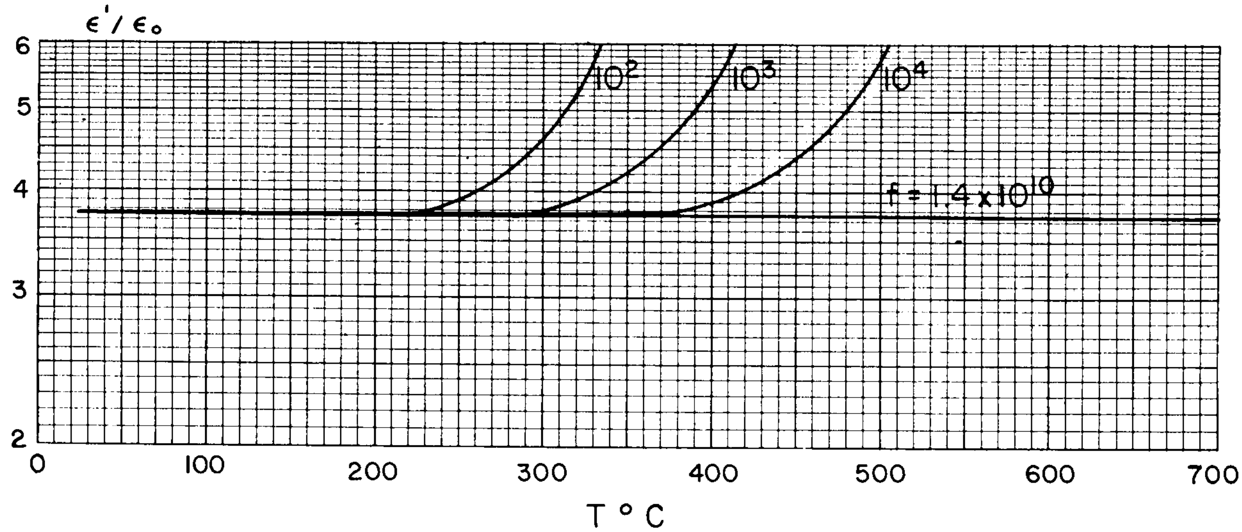
Corning



III A 3. Glasses

Fused Quartz

General Electric, Cleveland



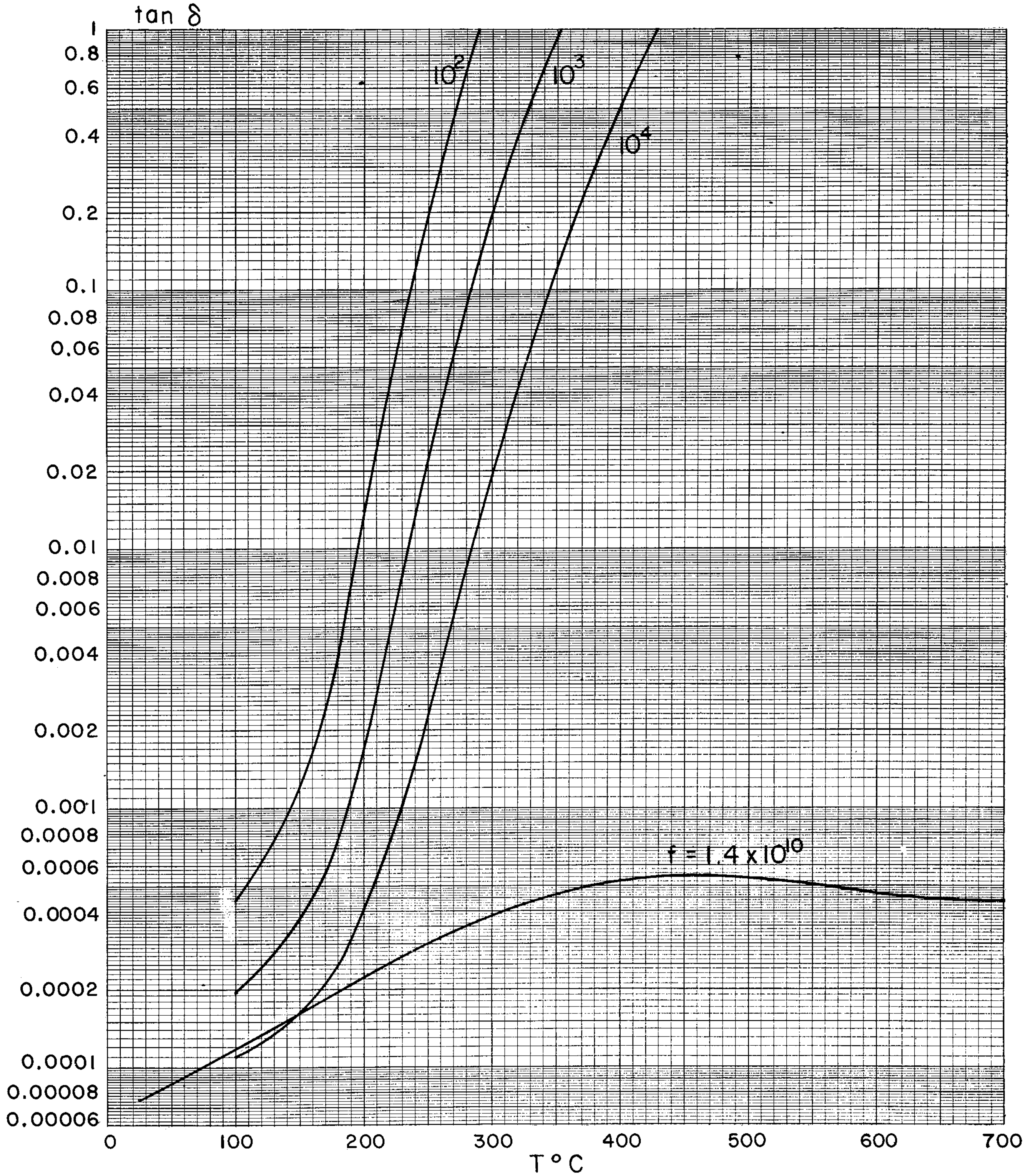
At 800°C, 1.4×10^{10} cycles, $\epsilon'/\epsilon_o = 3.76$ and $\tan\delta = 0.00048$.

At 1200°C, 5×10^{10} cycles, $\epsilon'/\epsilon_o = 3.8\text{-}3.9$ and $\tan\delta < 0.002$.

III A 3. Glasses

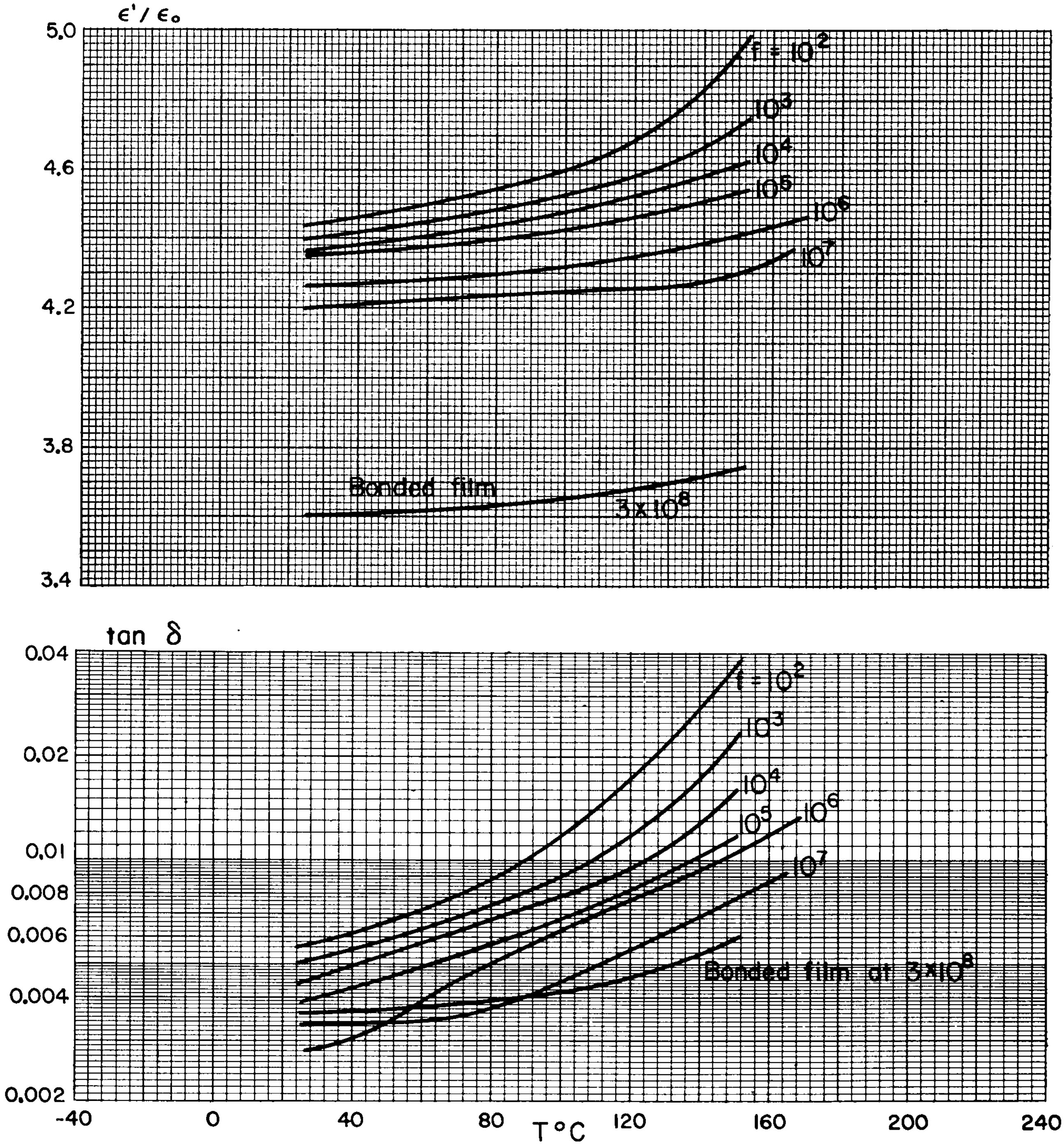
Fused Quartz

General Electric, Cleveland



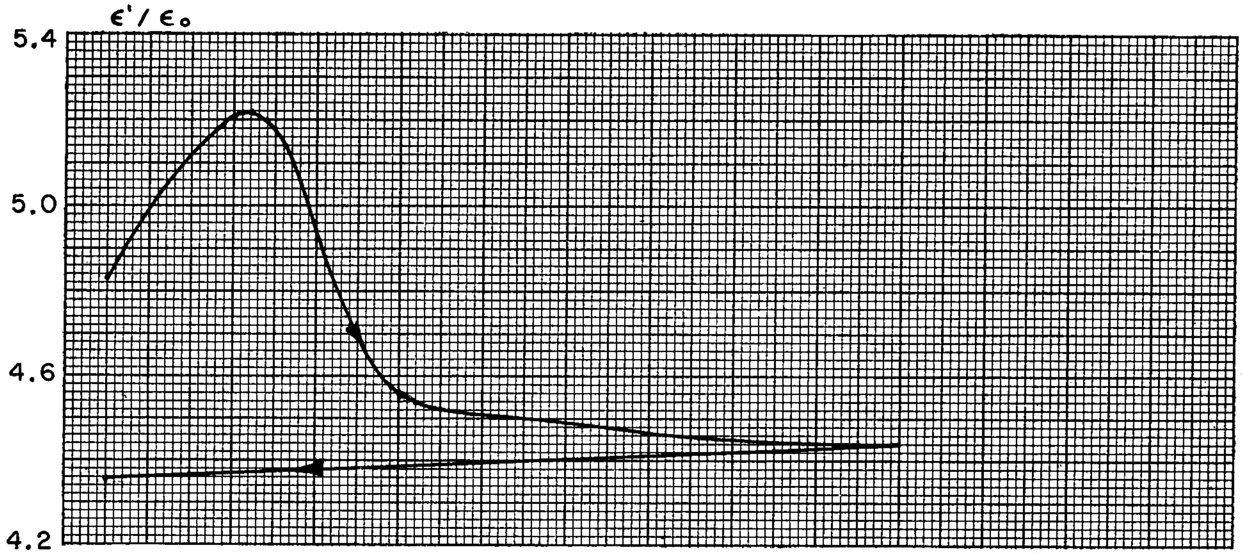
III A 4. Miscellaneous Inorganics

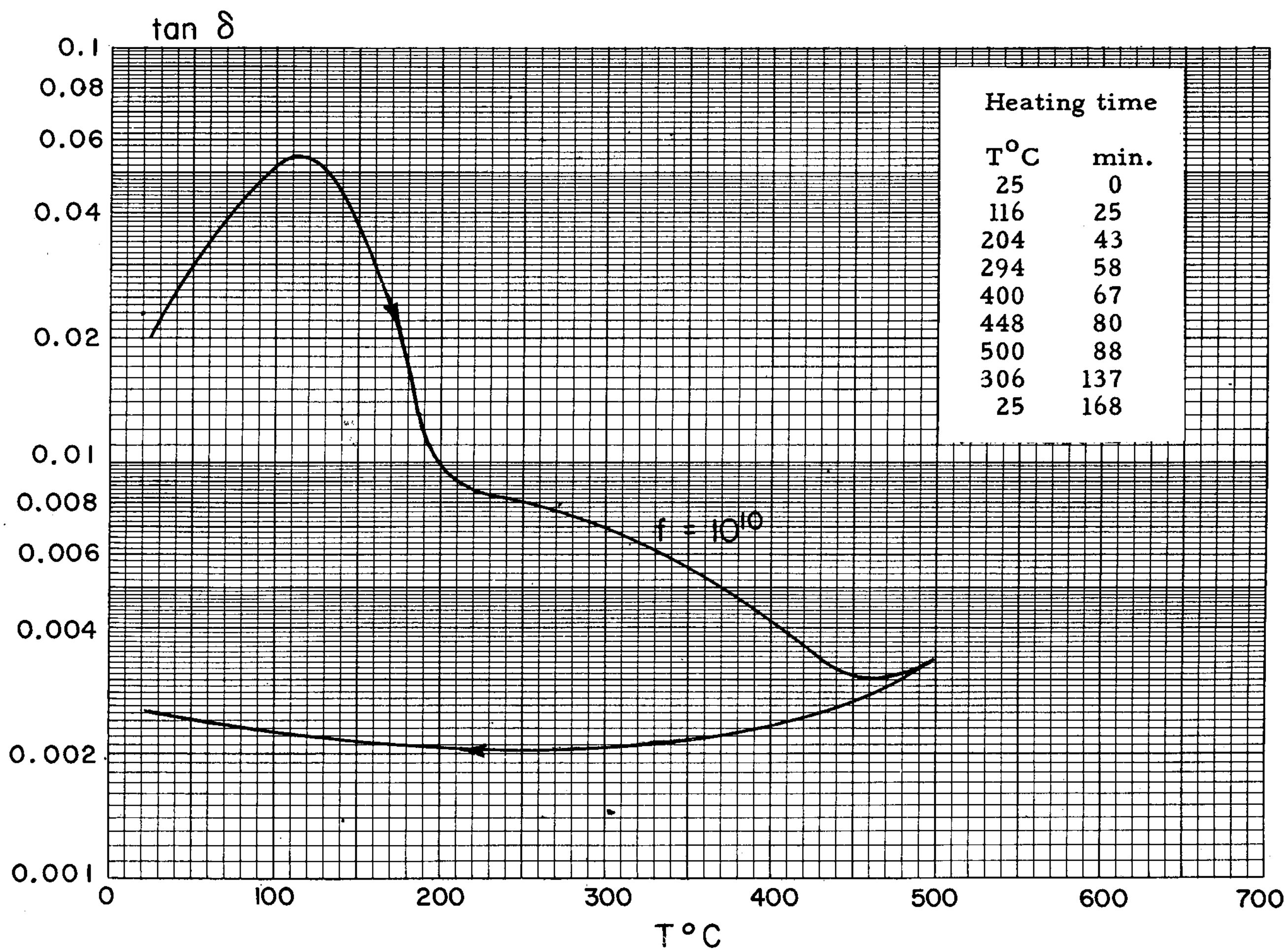
"Amplifilm" Aircraft Marine



III A 4. Miscellaneous Inorganics

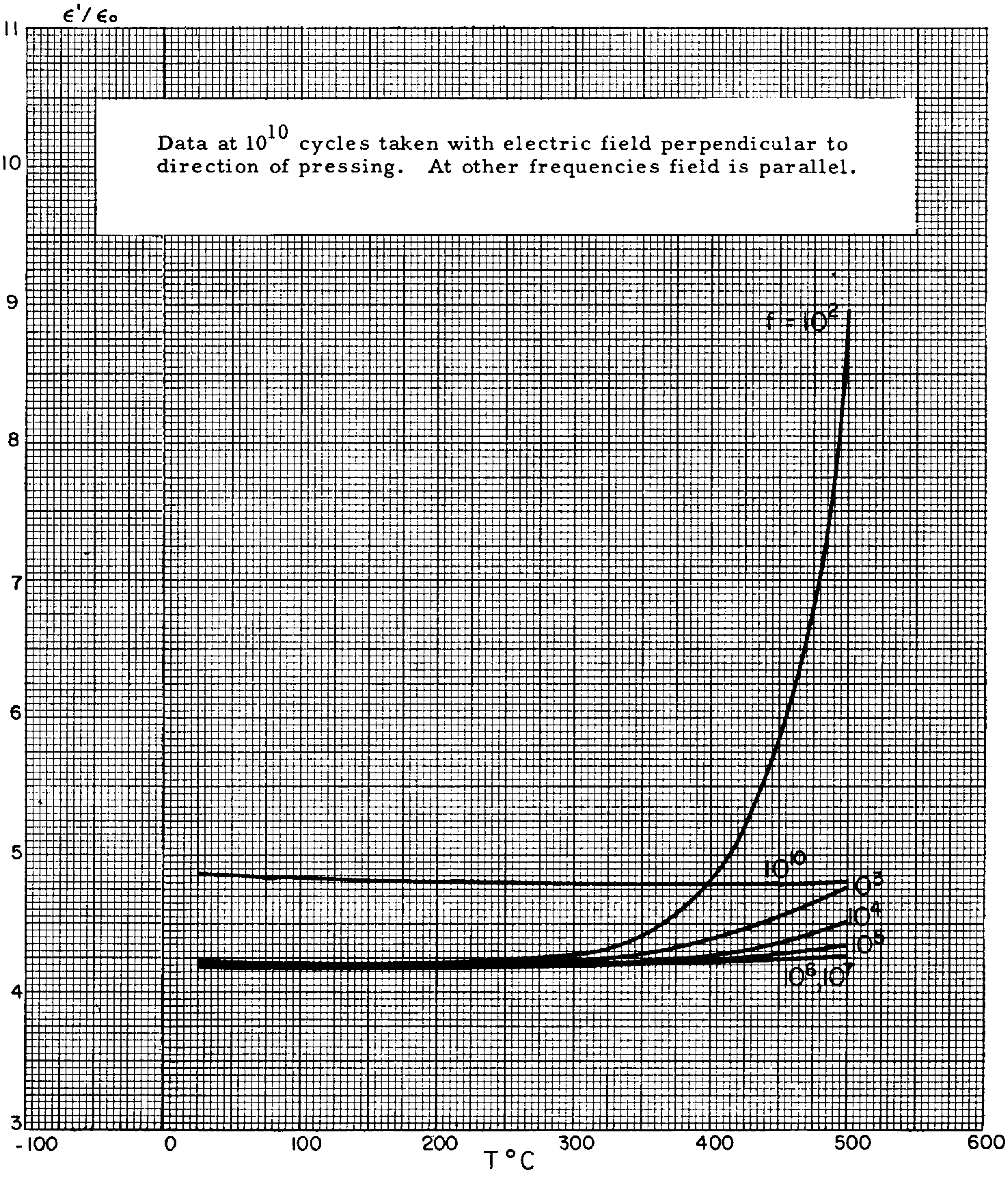
"AlSiMag" 602 American Lava





Hot Pressed Boron Nitride

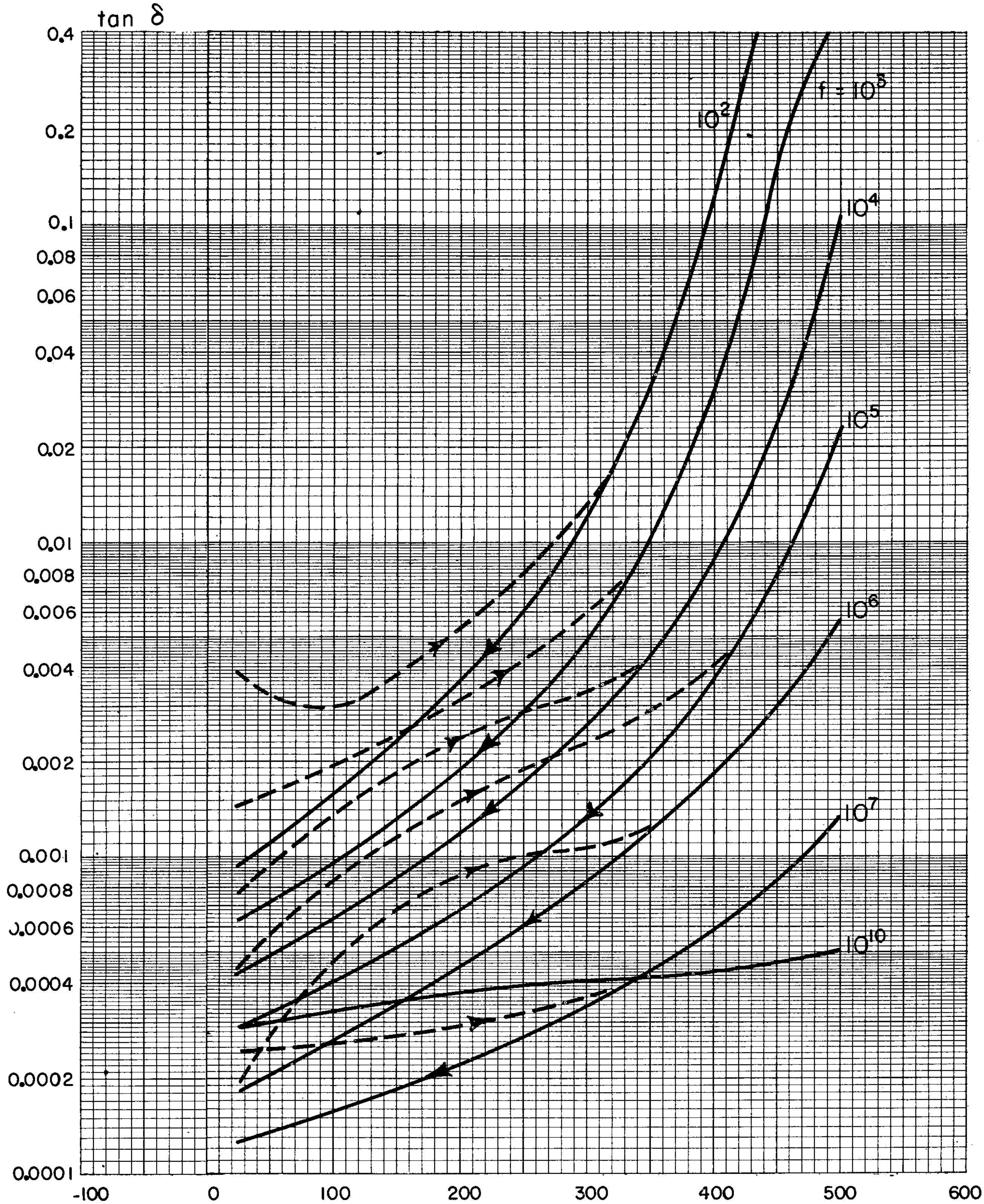
Carborundum Co.



III A 4. Miscellaneous Inorganics

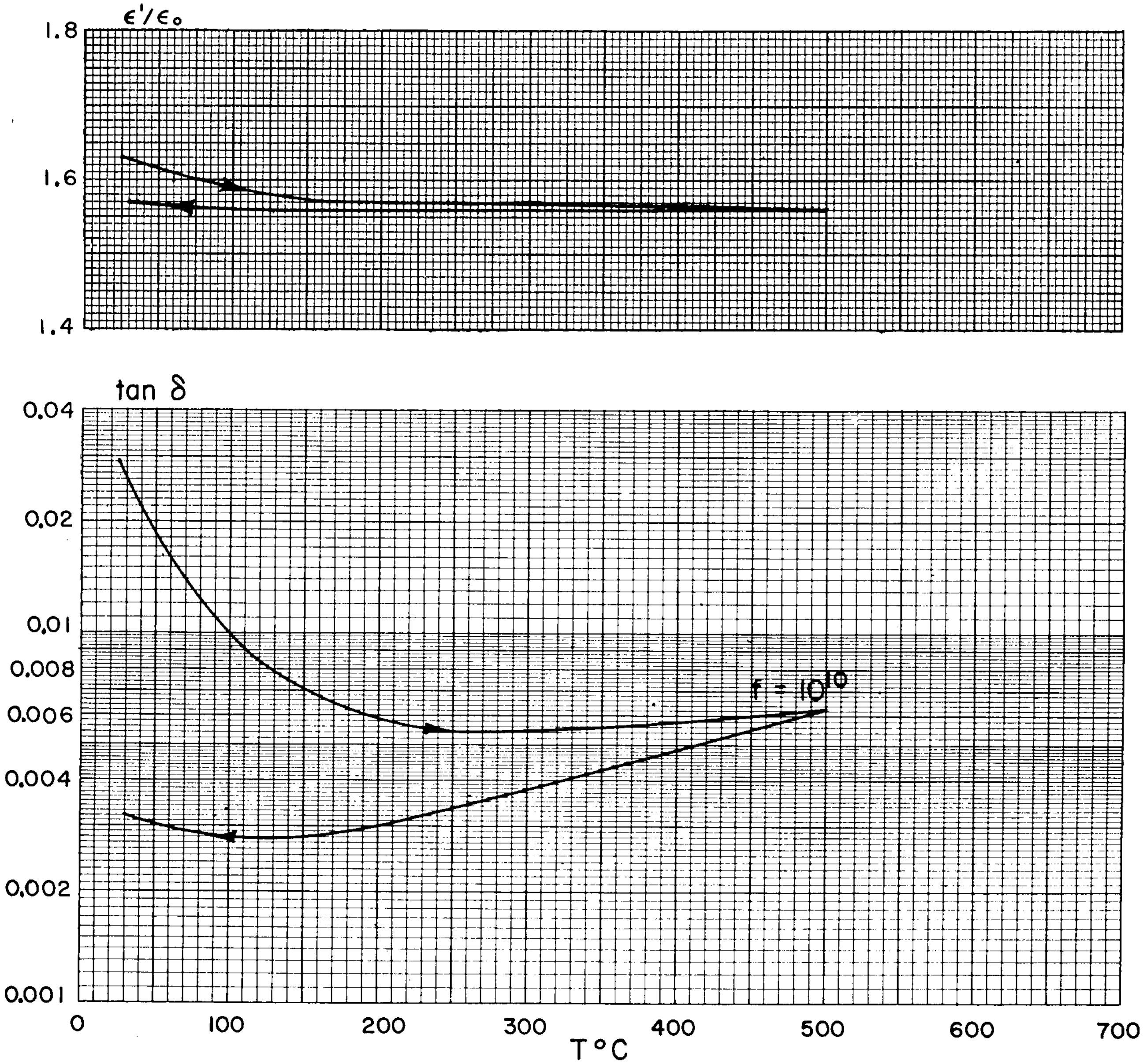
Hot Pressed Boron Nitride

Carborundum Co.



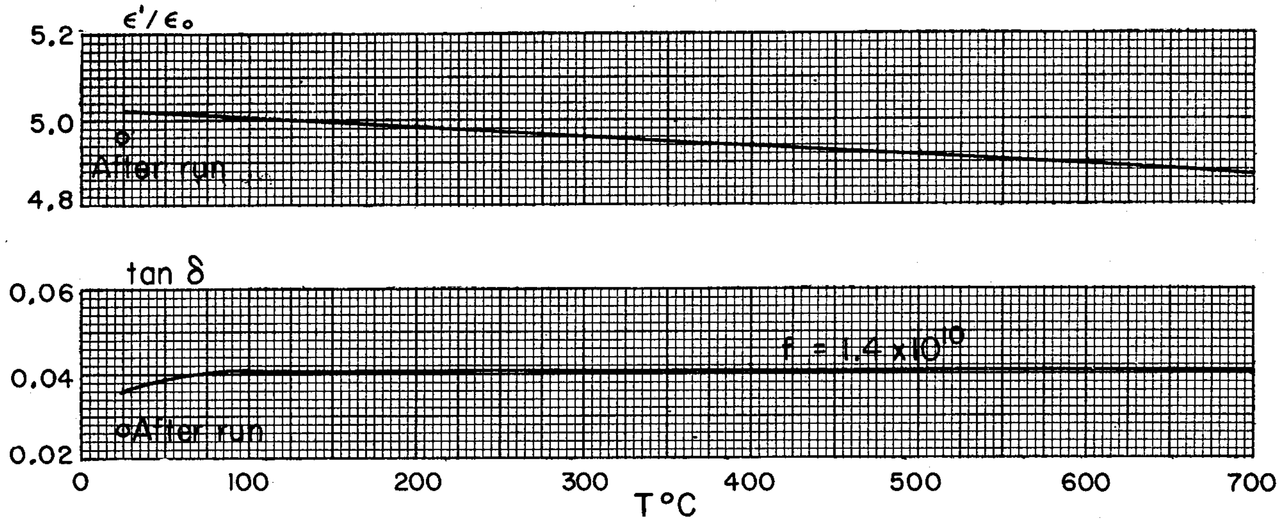
III A 4. Miscellaneous Inorganics

"Fiberfrax" Board (density 0.50 gm/cc) Carborundum

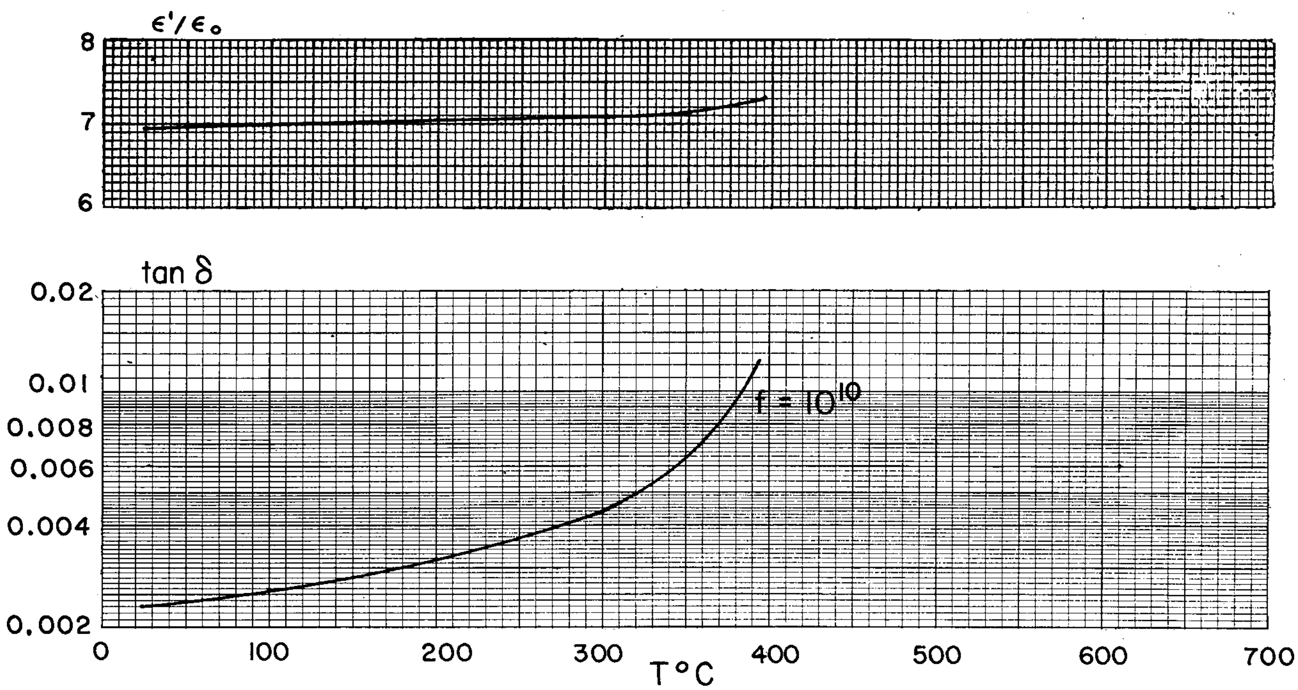


III A 4. Miscellaneous Inorganics

Silicon nitride (0.75) - Boron nitride (0.25) **Carborundum**

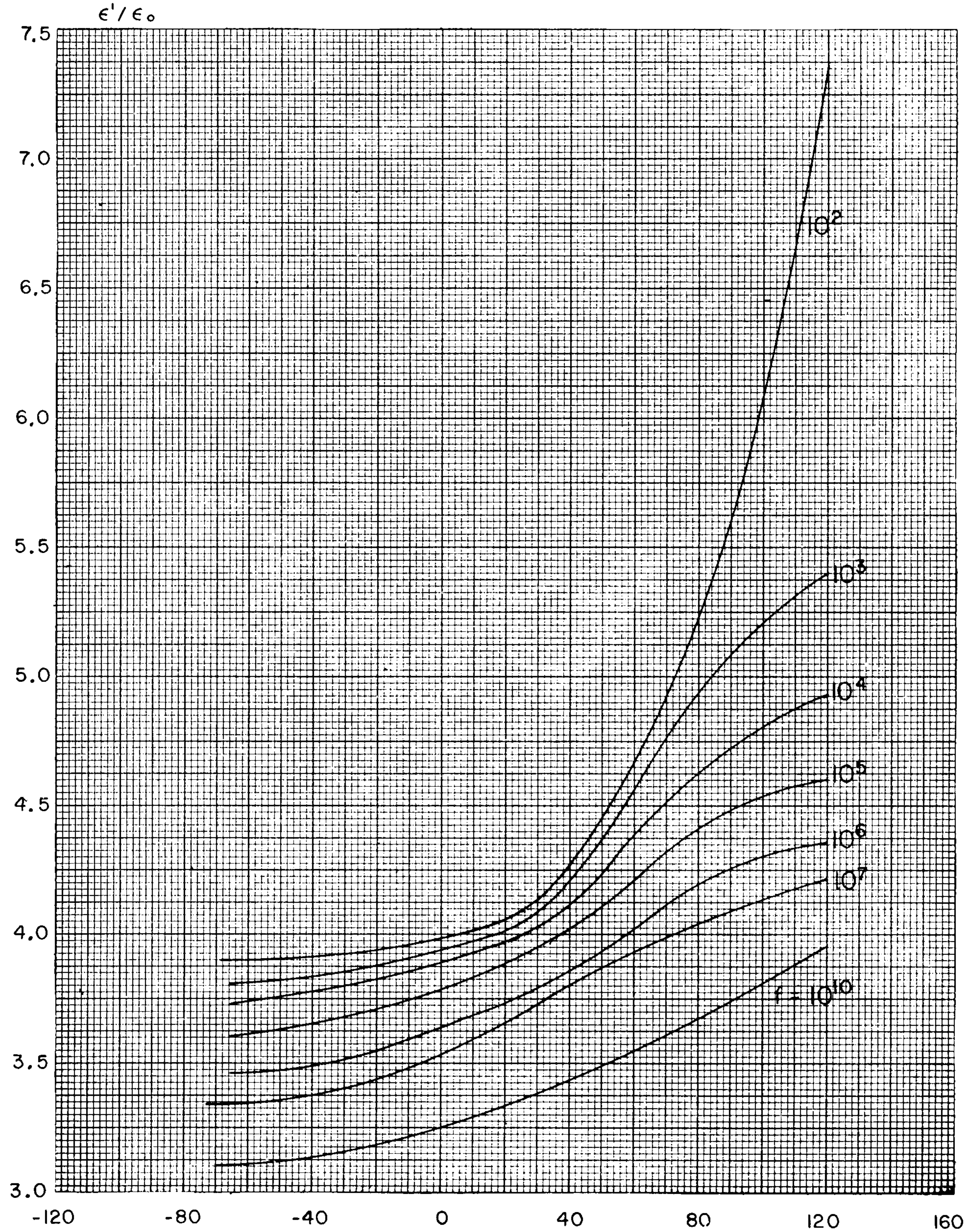


"Supramica" 500 (density 3.04 gm/cc) **Mycalex**



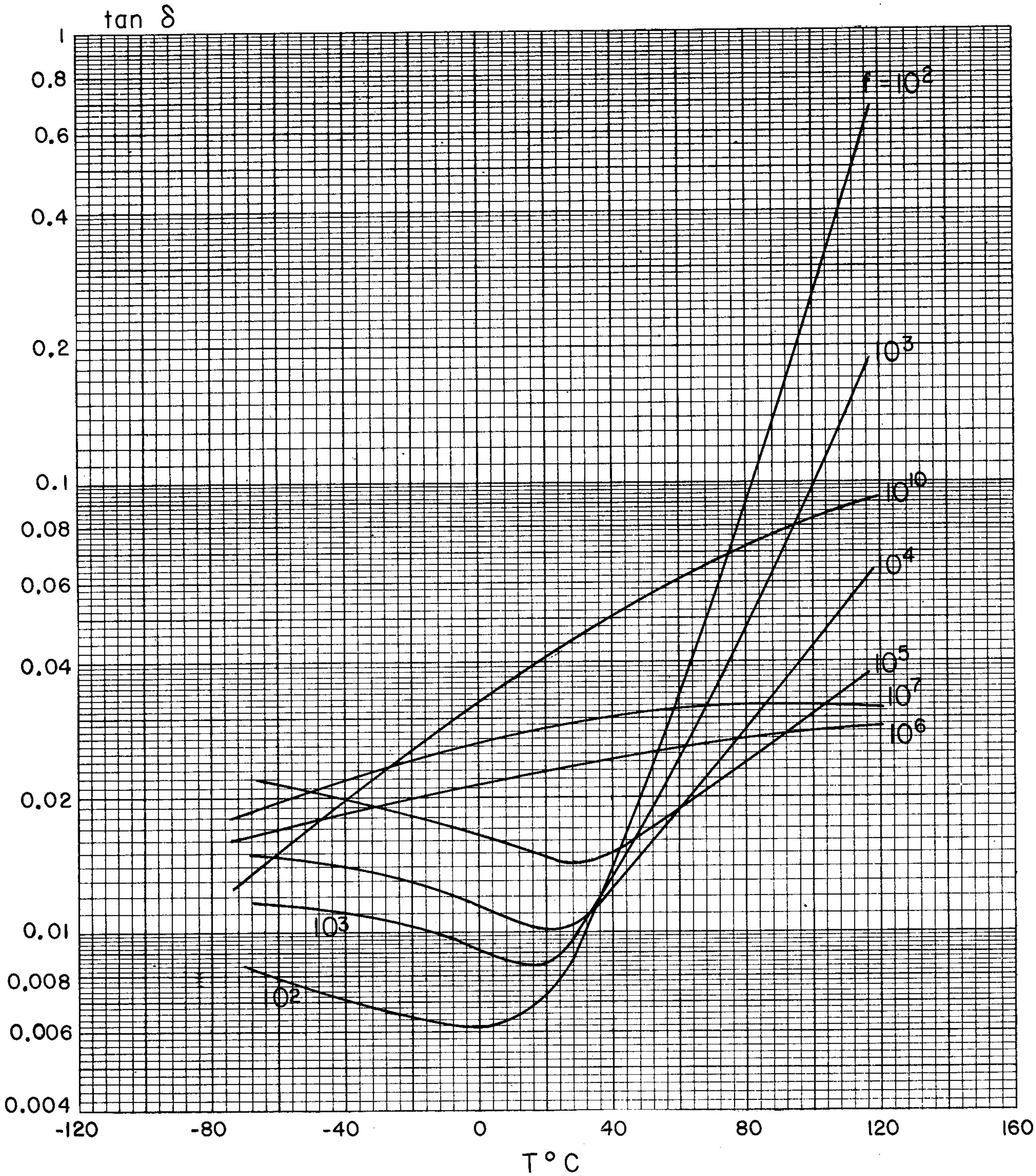
III B 1. Phenolics

"Dilecto" (hot punching) XXX-P-26 Continental Diamond



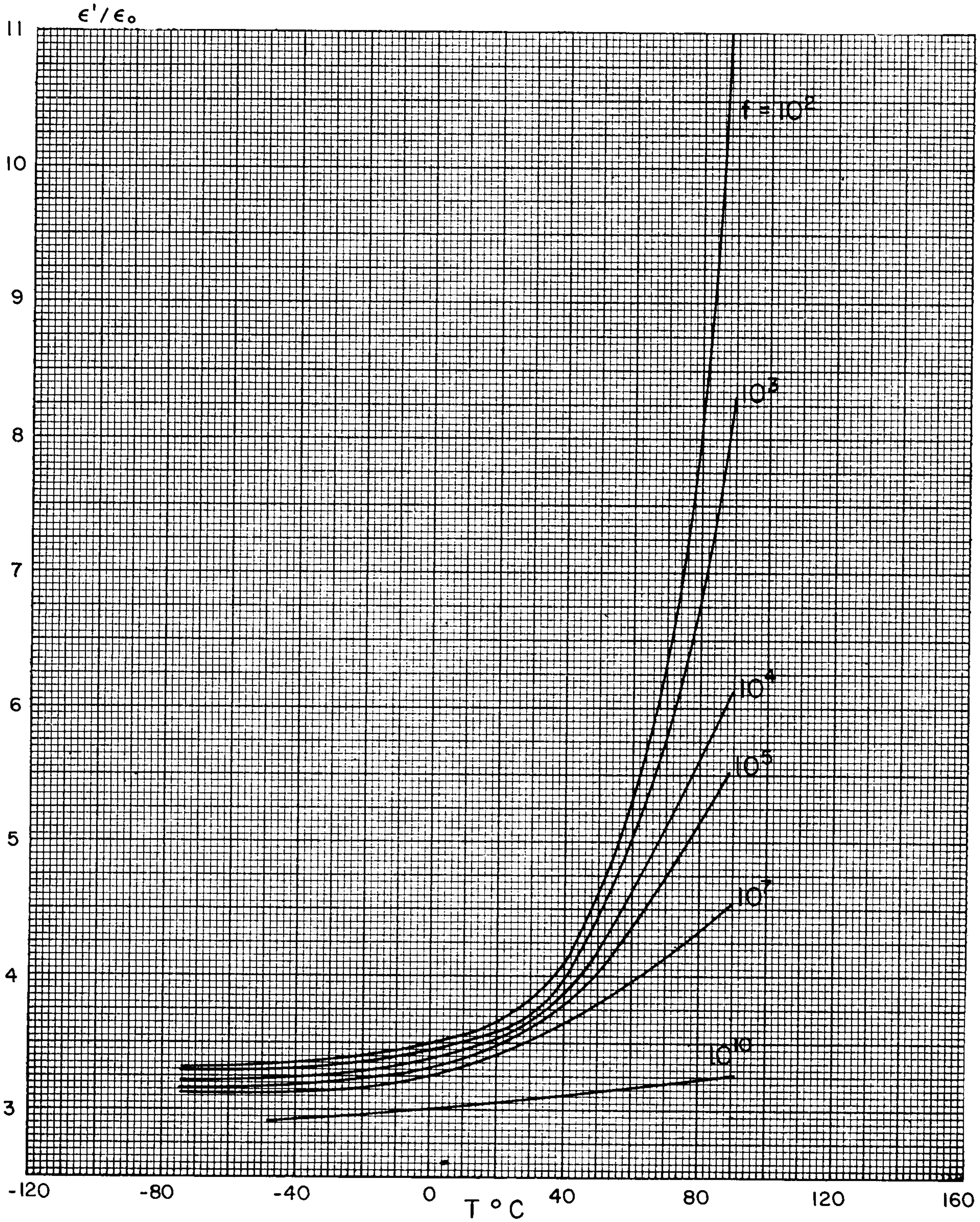
III B 1. Phenolics

"Dilecto" (hot punching) XXX-P-26 Continental Diamond



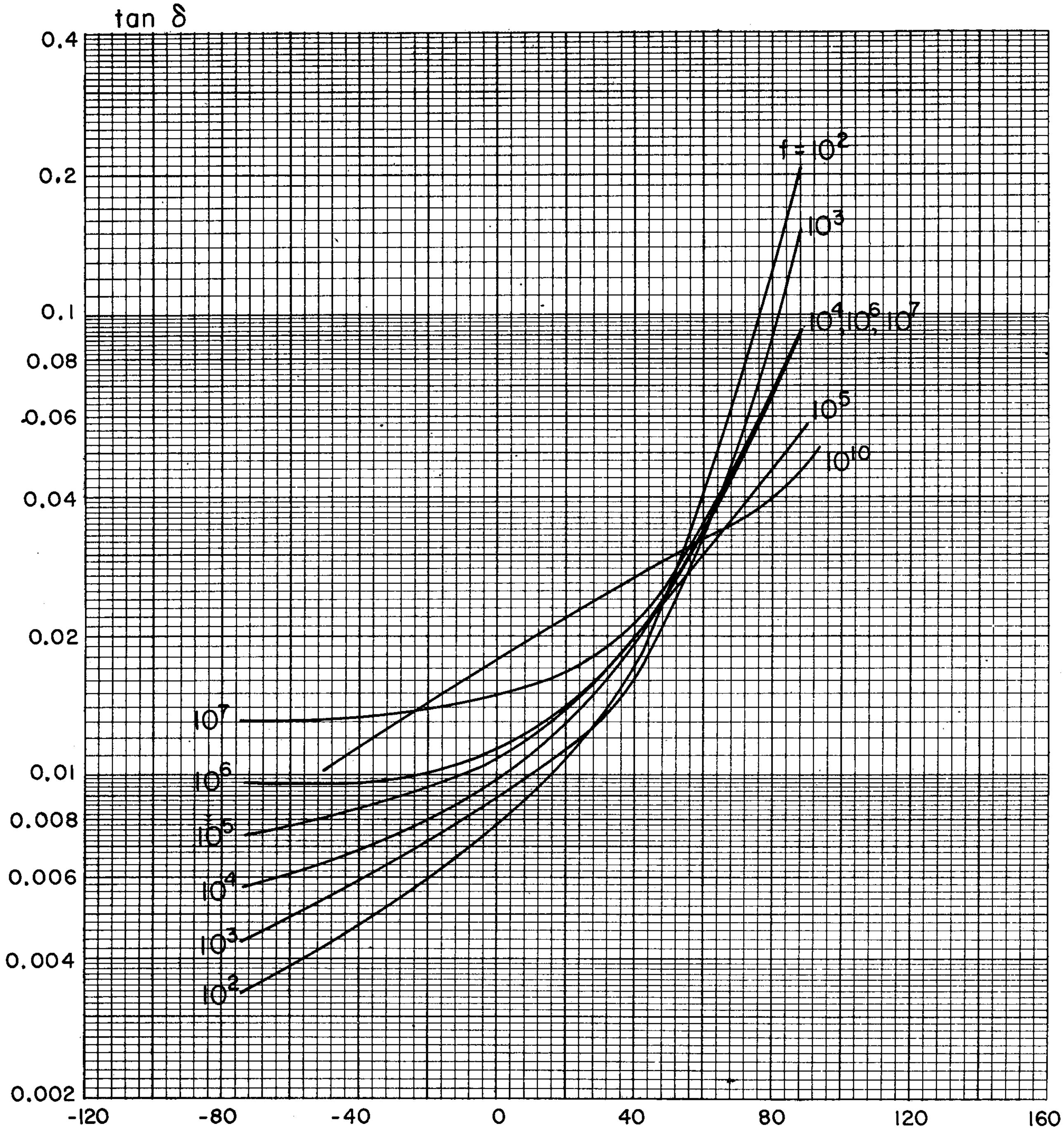
III B 1. Phenolics

"Dilecto" ("Mecoboard") Continental Diamond



III B 1. Phenolics

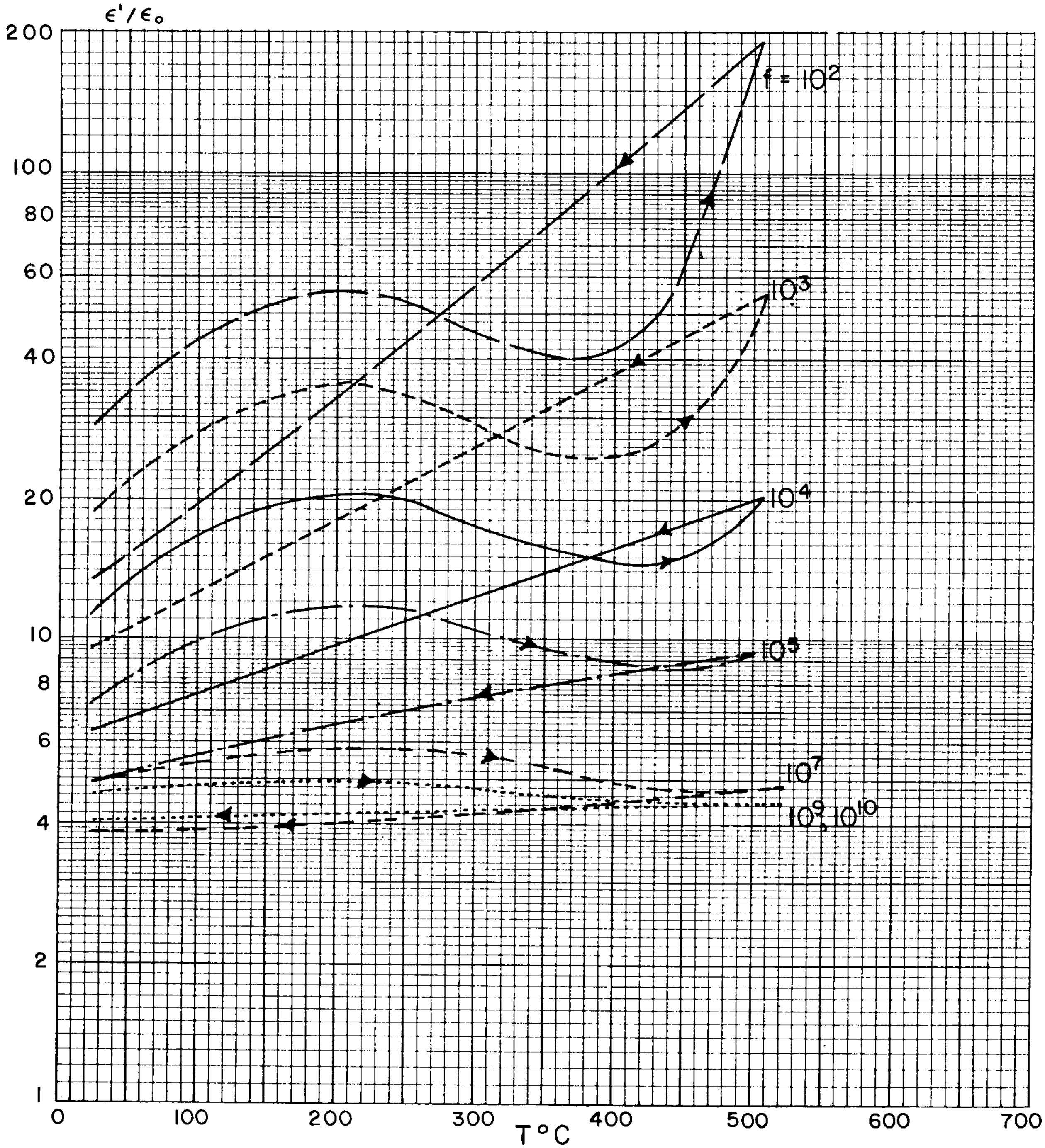
"Dilecto" ("Mecoboard") Continental Diamond



III B 1. Phenolics

Phenolic - asbestos laminate

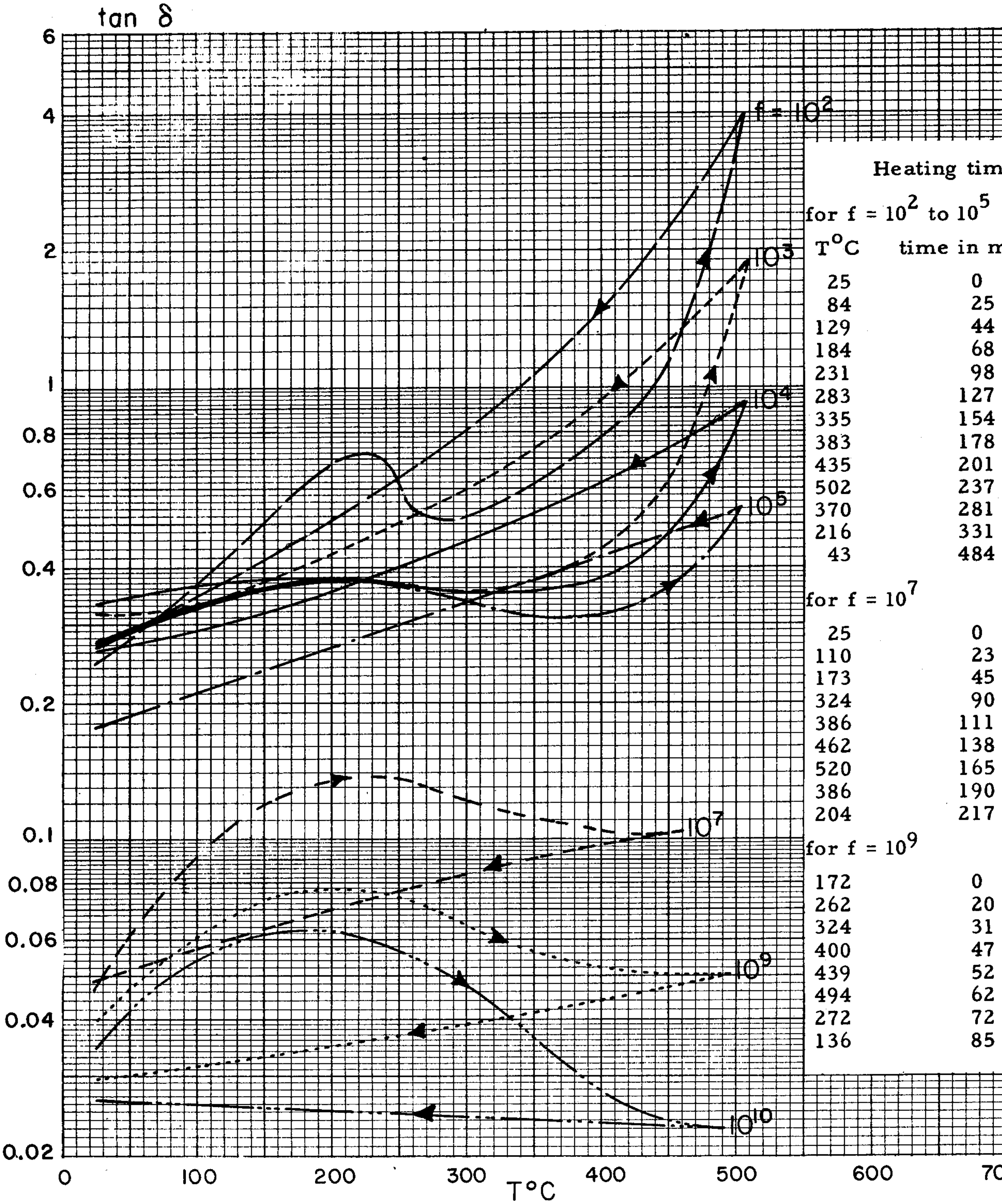
Goodyear Aircraft Corp.



III B 1. Phenolics

Phenolic- asbestos laminate

Goodyear Aircraft Corp.



Heating time

for f = 10^2 to 10^5

T°C	time in minutes
25	0
84	25
129	44
184	68
231	98
283	127
335	154
383	178
435	201
502	237
370	281
216	331
43	484

for f = 10^7

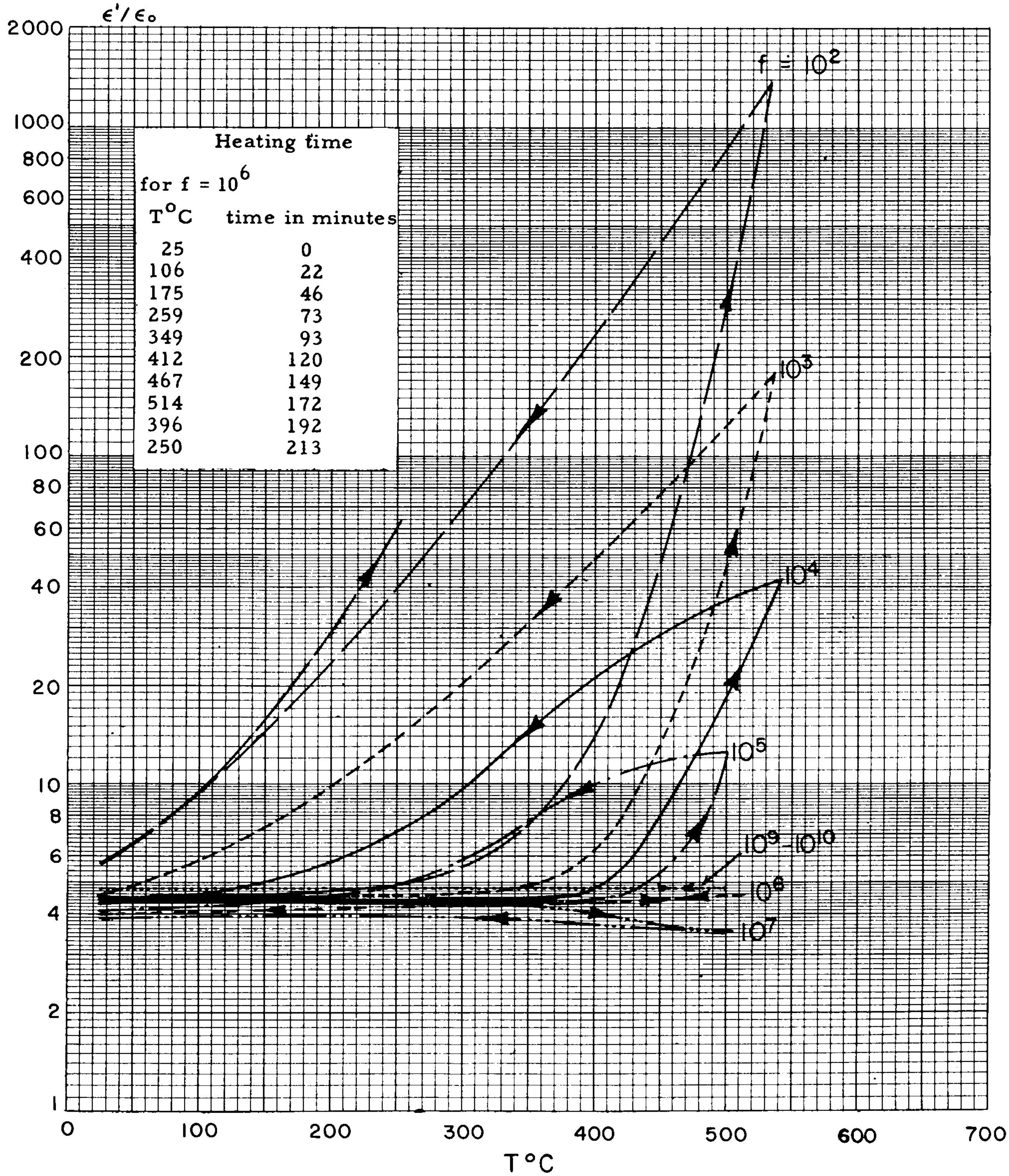
T°C	time in minutes
25	0
110	23
173	45
324	90
386	111
462	138
520	165
386	190
204	217

for f = 10^9

T°C	time in minutes
172	0
262	20
324	31
400	47
439	52
494	62
272	72
136	85

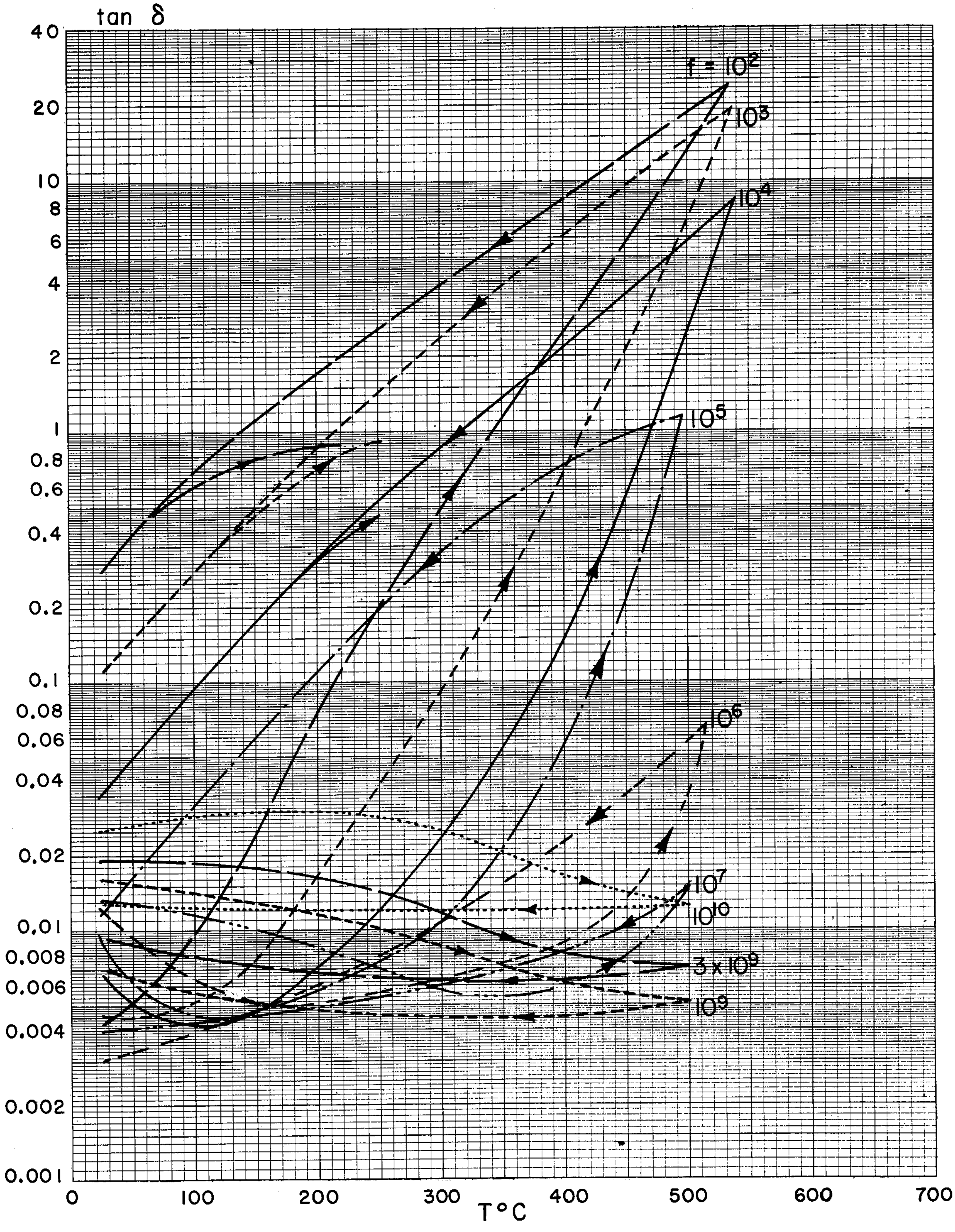
III B 1. Phenolics

Phenolic-"fiberglas"laminate, pressed Goodyear Aircraft Corp.



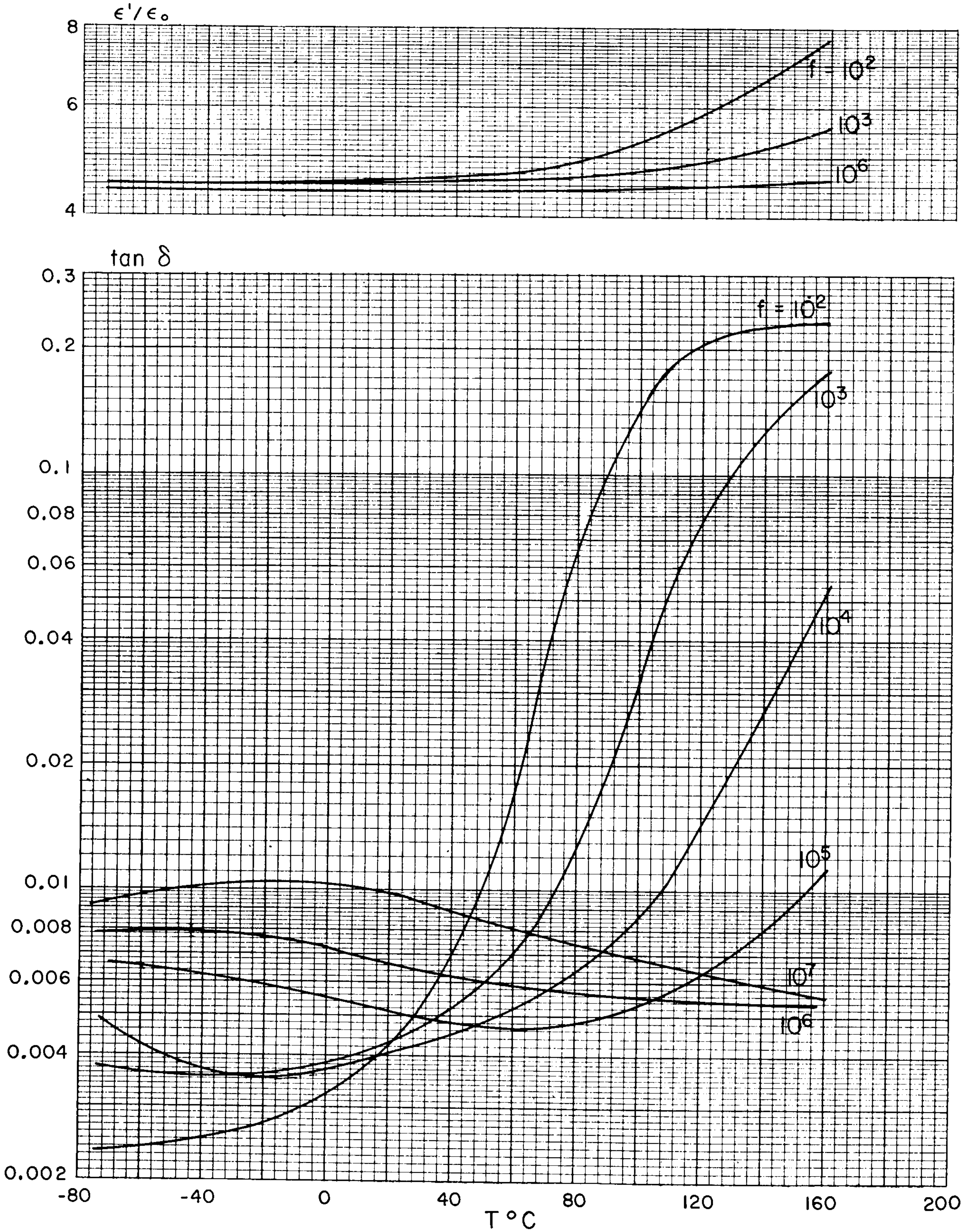
Phenolic-"fiberglas"laminate, pressed

Goodyear Aircraft Corp.



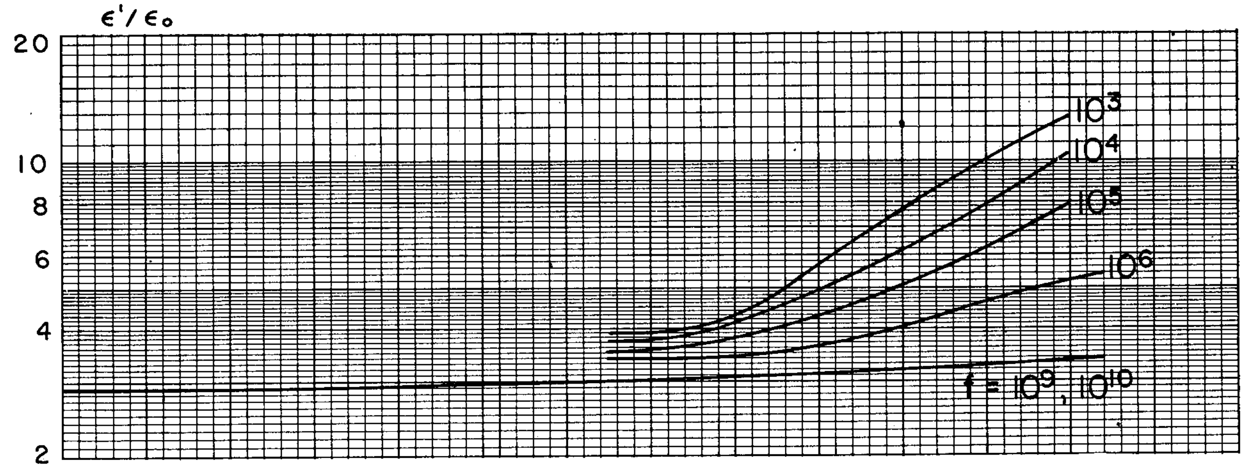
III B 2. Melamine Formaldehyde

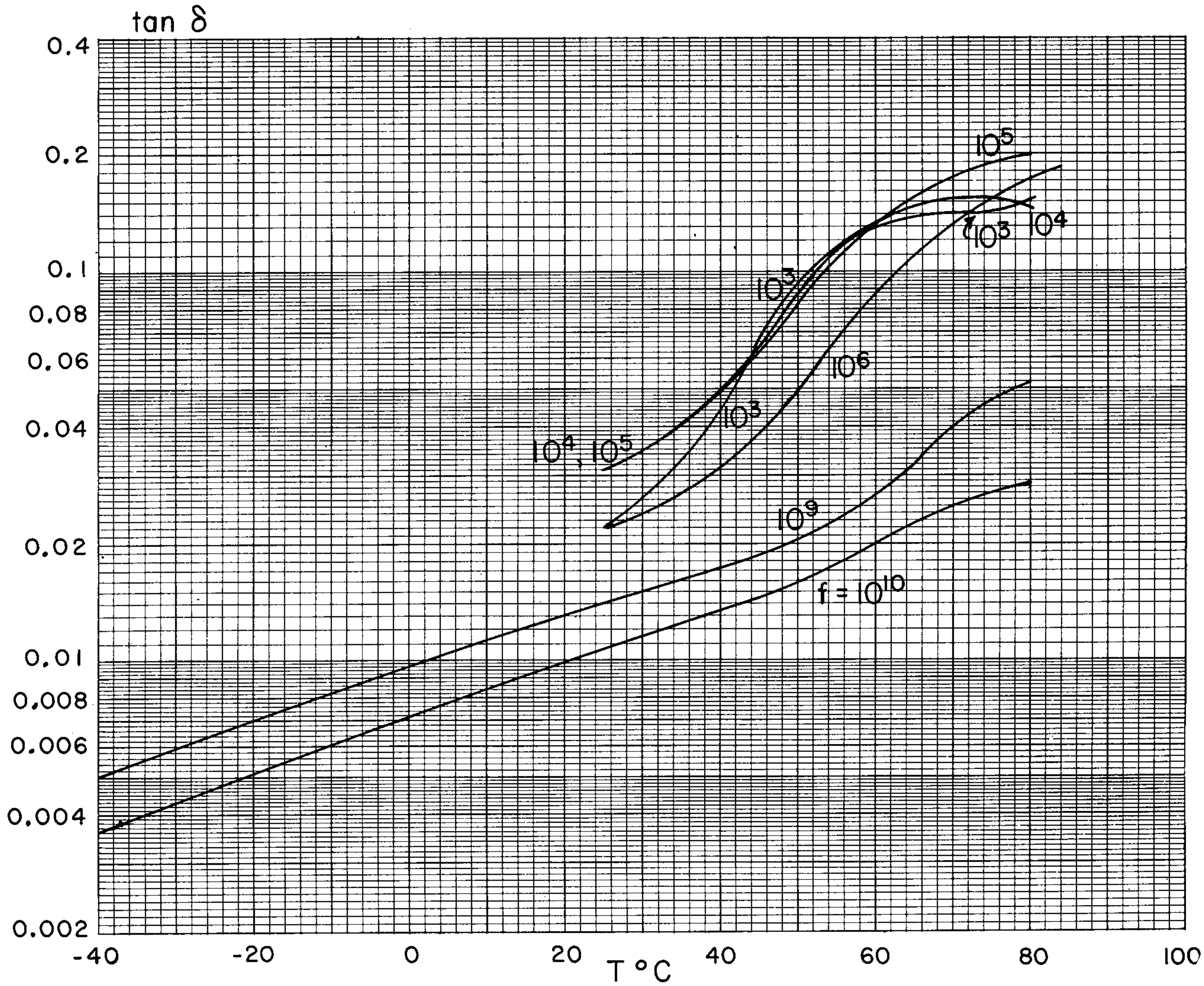
"Dilecto" GM-1 — Continental Diamond



III B 3. Polyamide Resin

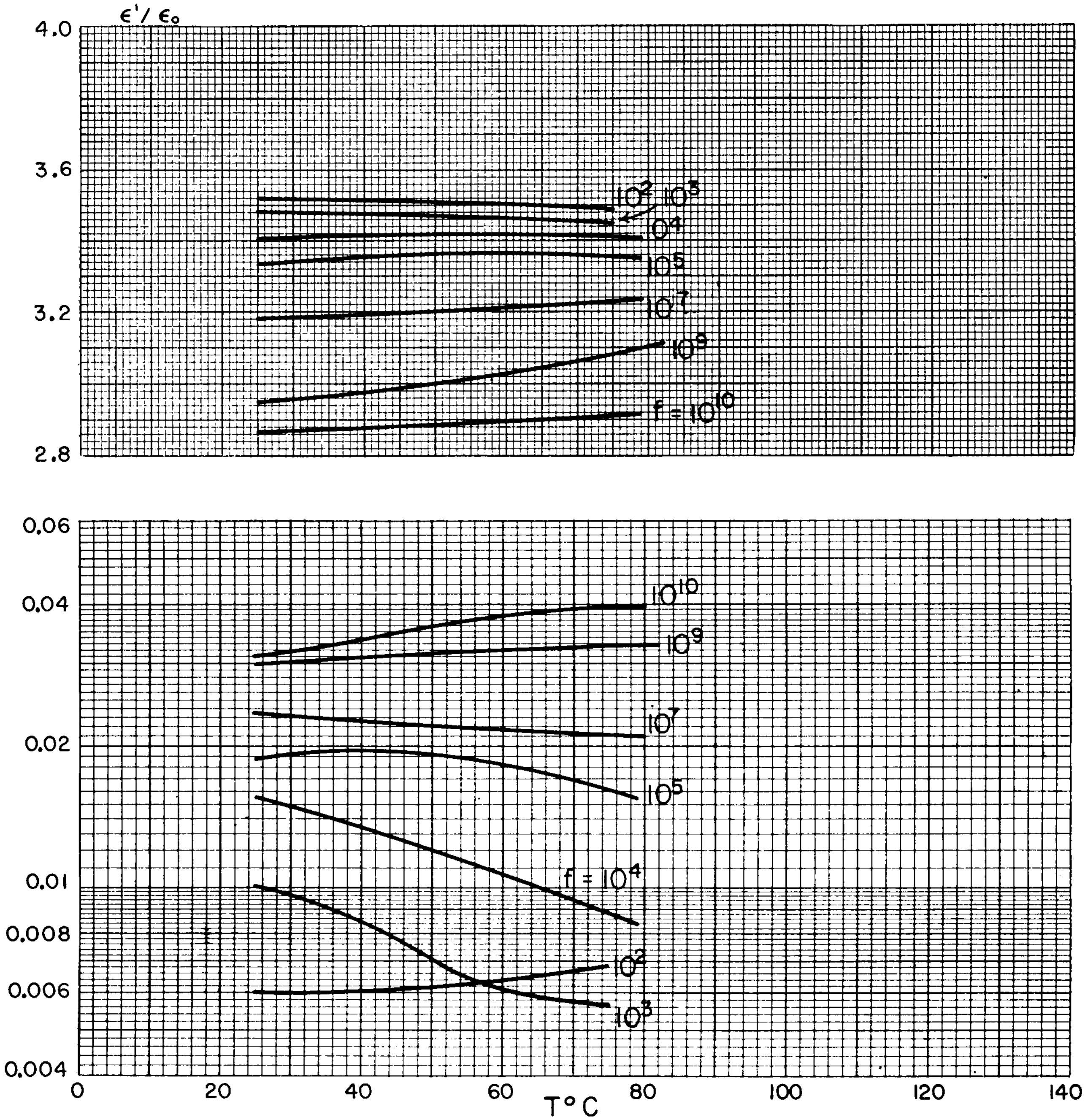
"Nylon" FM 10, 001 du Pont





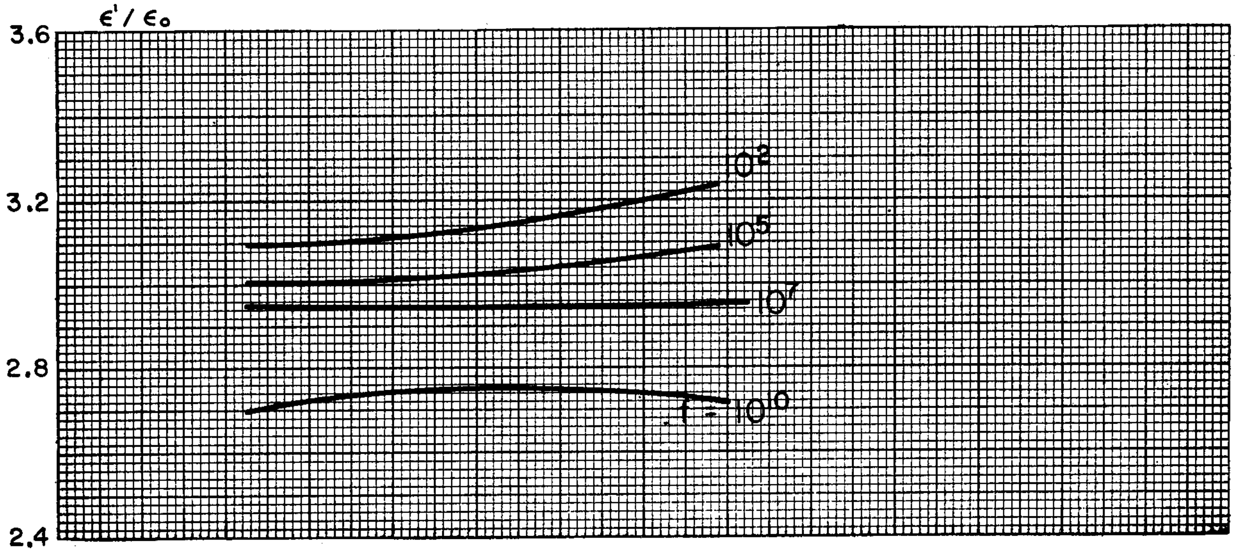
III B 4. Cellulose Derivatives

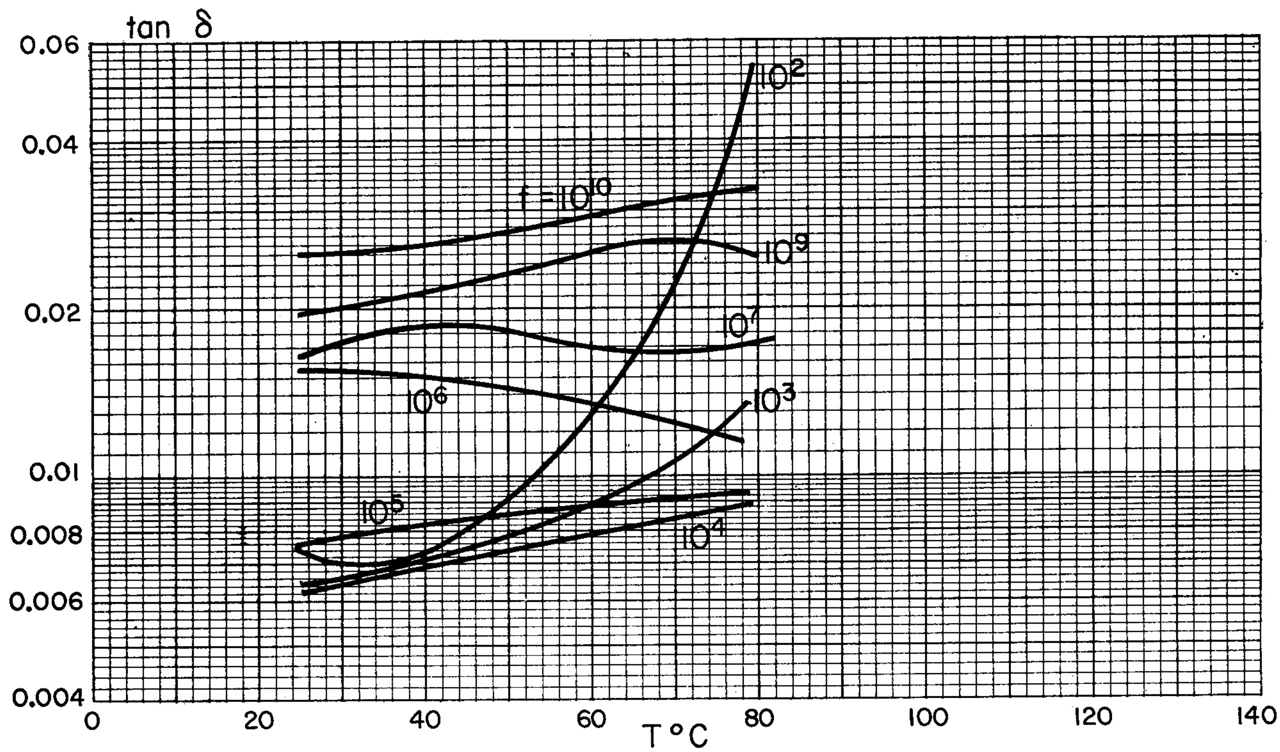
"Forticel" (No. 28102, 8% plasticizer) Celanese



III B 4. Cellulose Derivatives

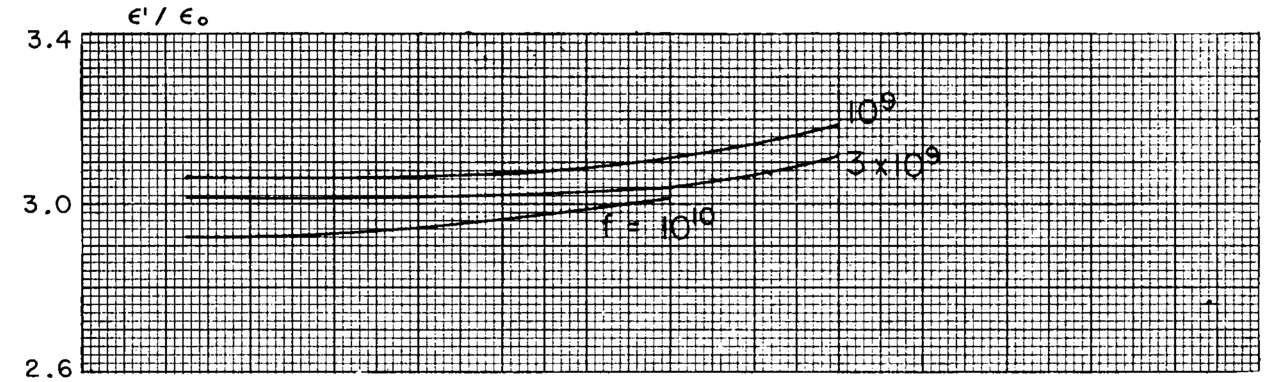
"Ethocel" LT5 Dow Chemical

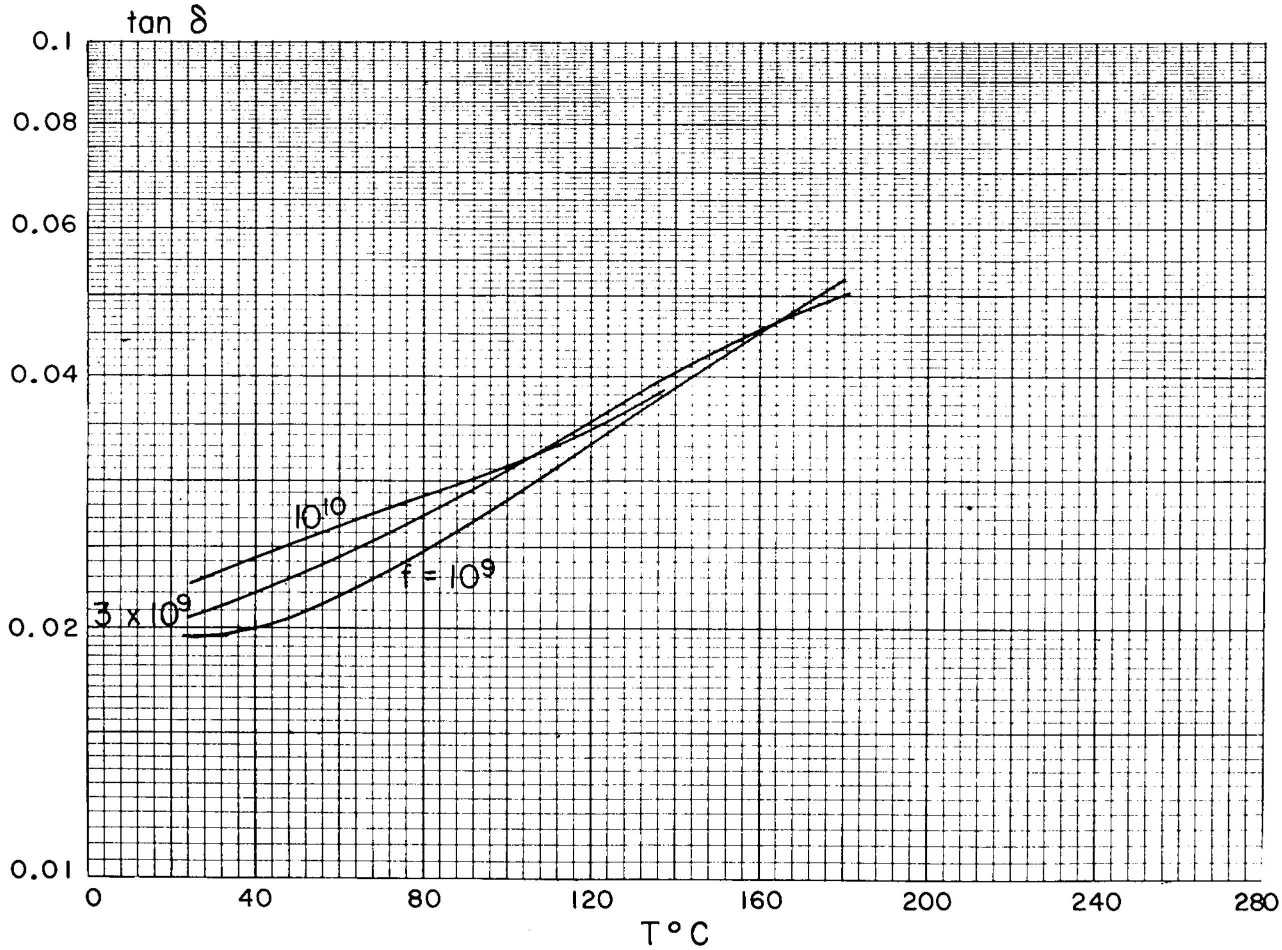




III B 4. Cellulose Derivatives

"CTA" du Pont film dept.

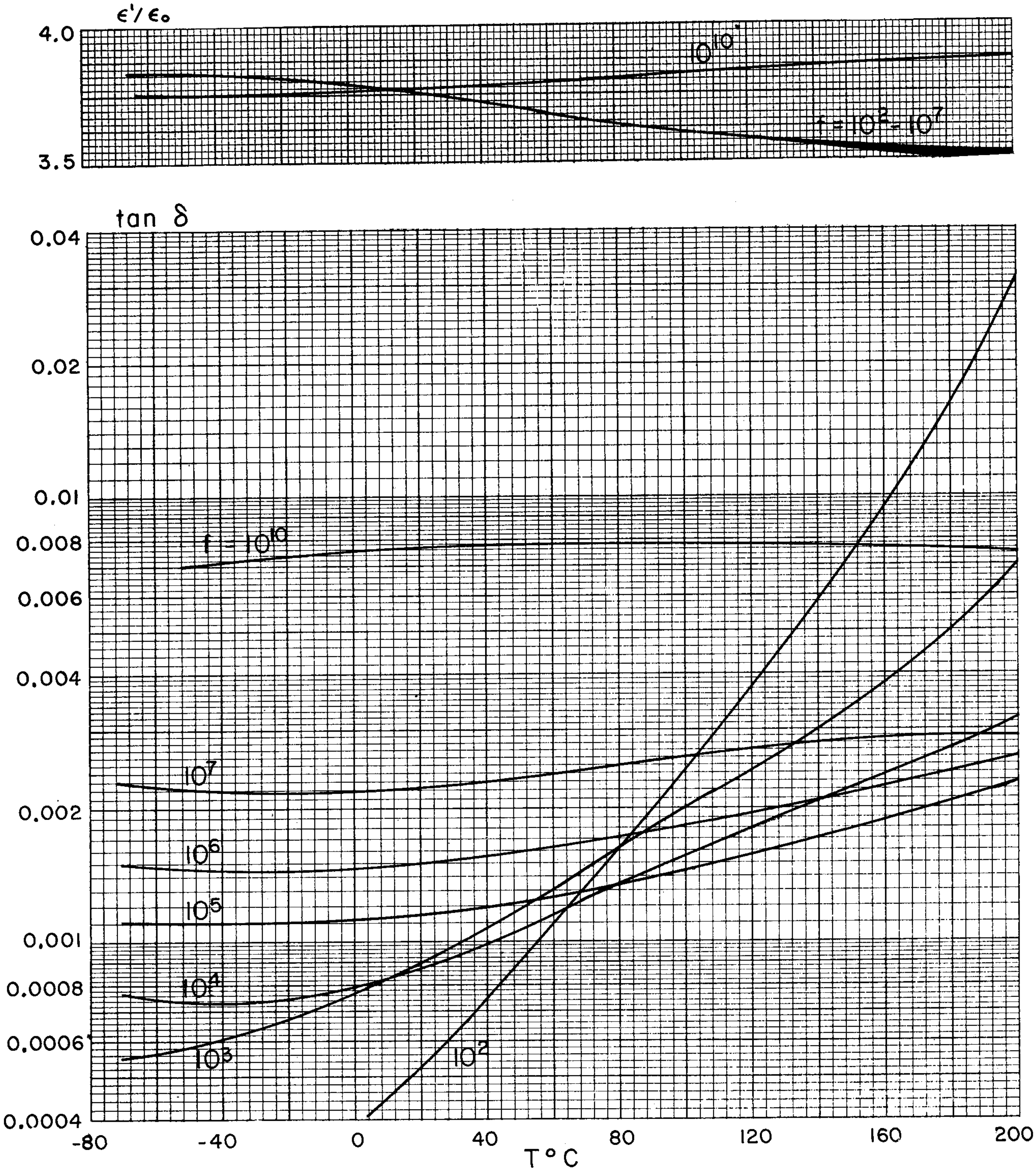




III B 5. Silicone Resins

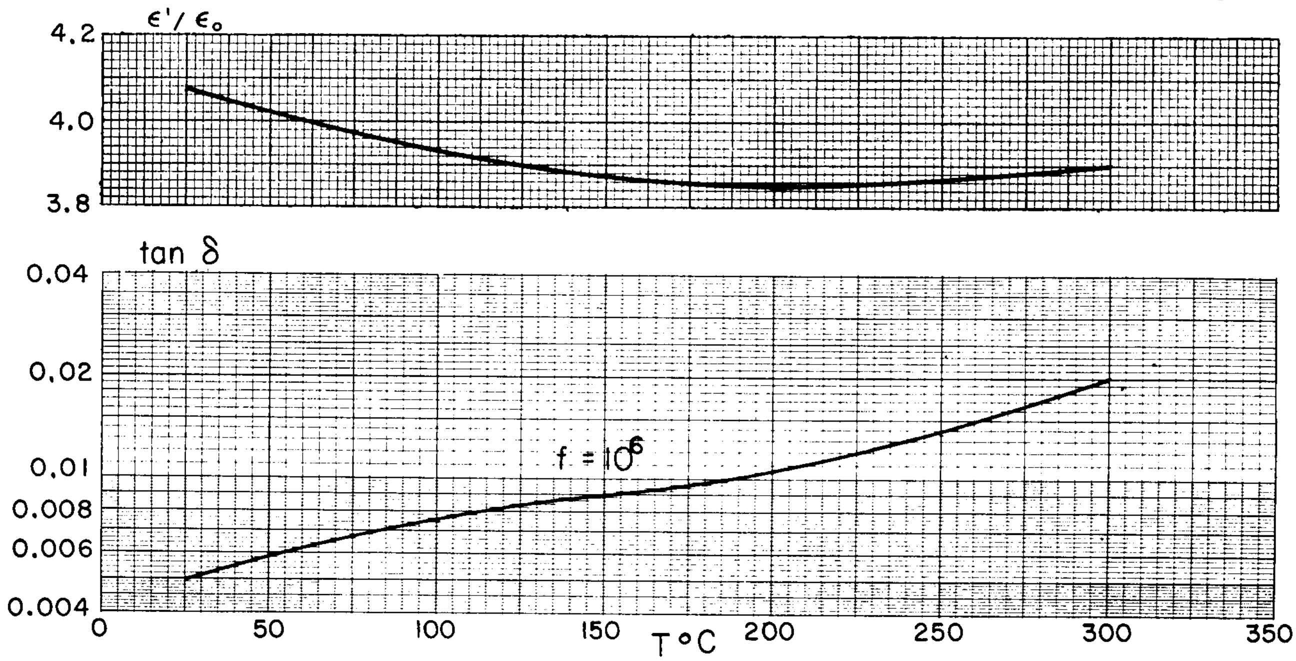
"Dilecto" (Silicone glass laminate) GB-261S

Continental Diamond

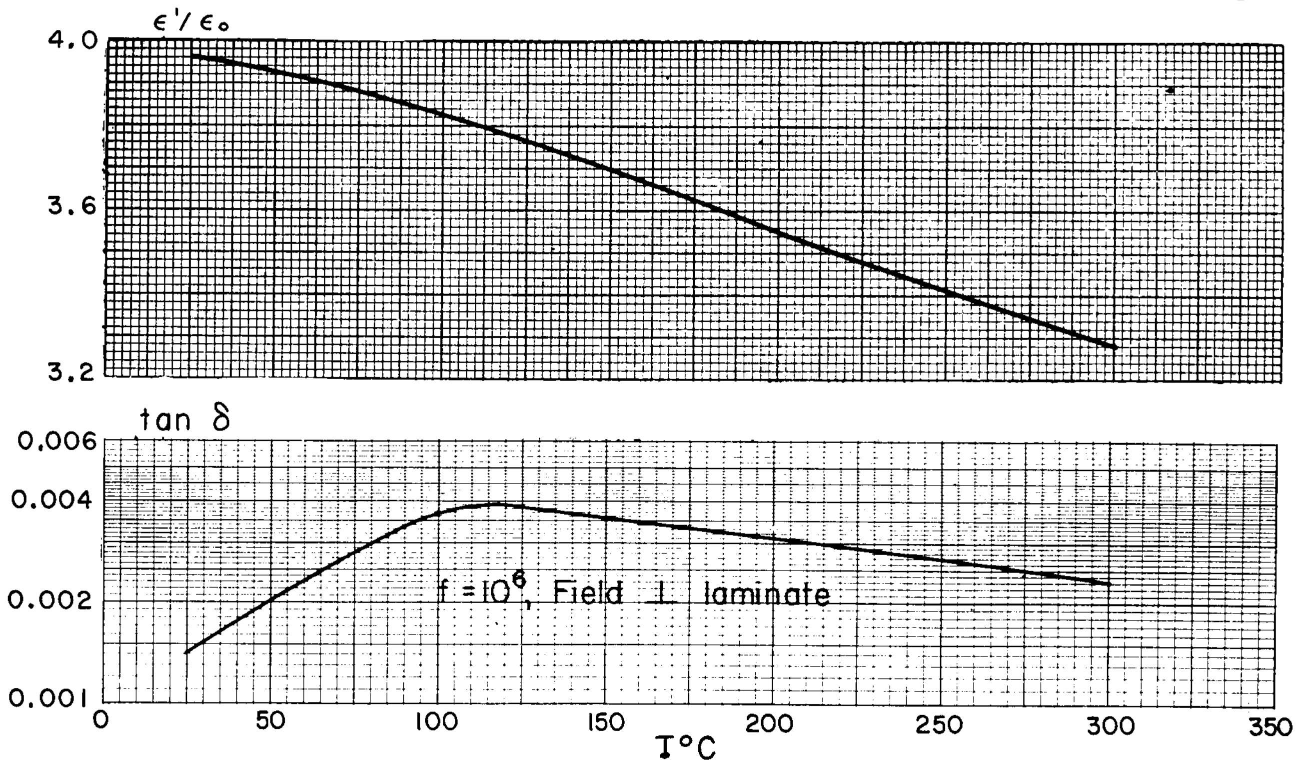


III B 5. Silicone Resins

DC 301 Molding Compound — Dow Corning



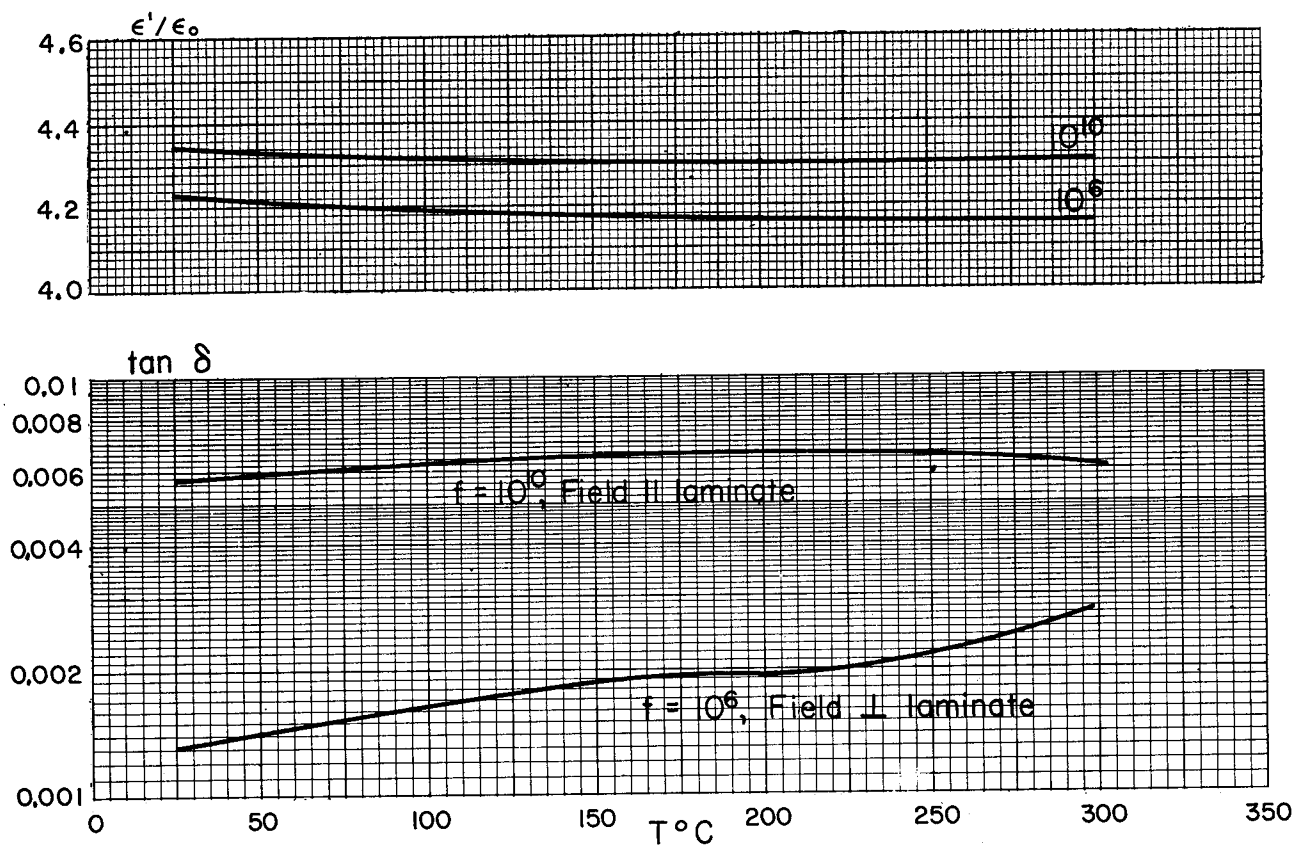
Dow Corning 2105 "Fiberglas" laminate — Dow Corning



III B 5. Silicone Resins

Dow Corning 2106 "Fiberglas" laminate

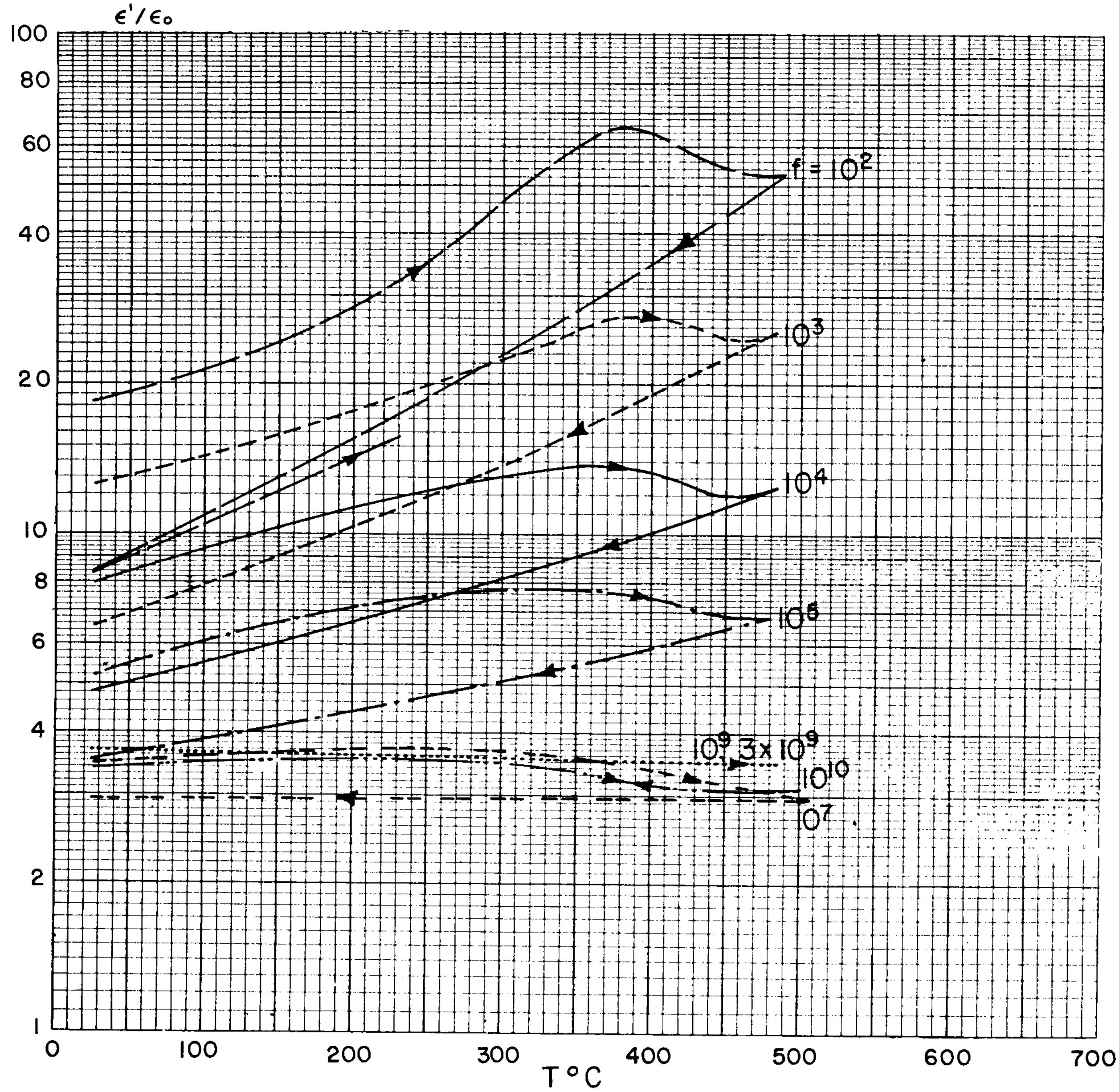
Dow Corning



III B 5. Silicone Resins

Silicone-asbestos laminate

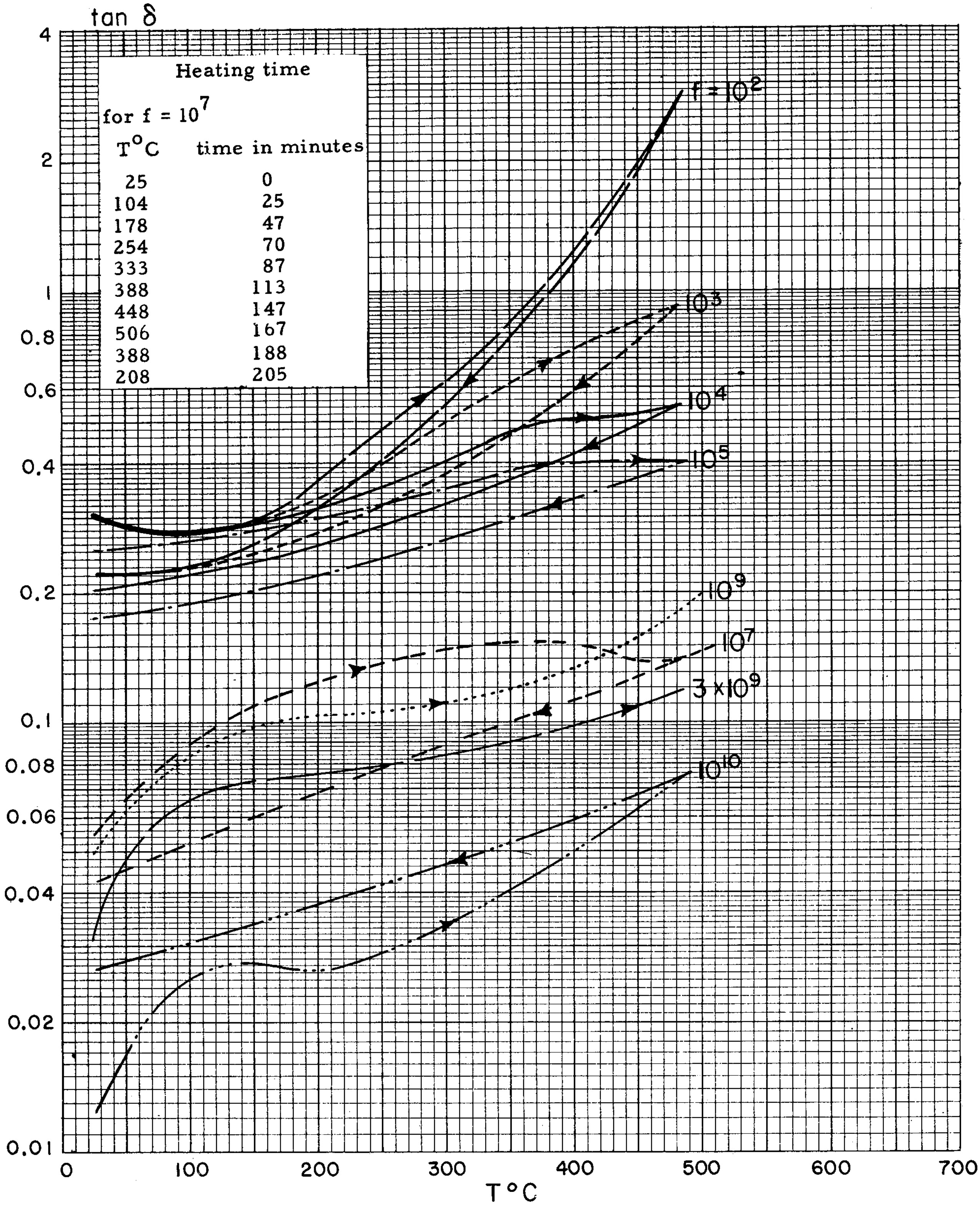
Goodyear Aircraft Corp.



III B 5. Silicone Resins

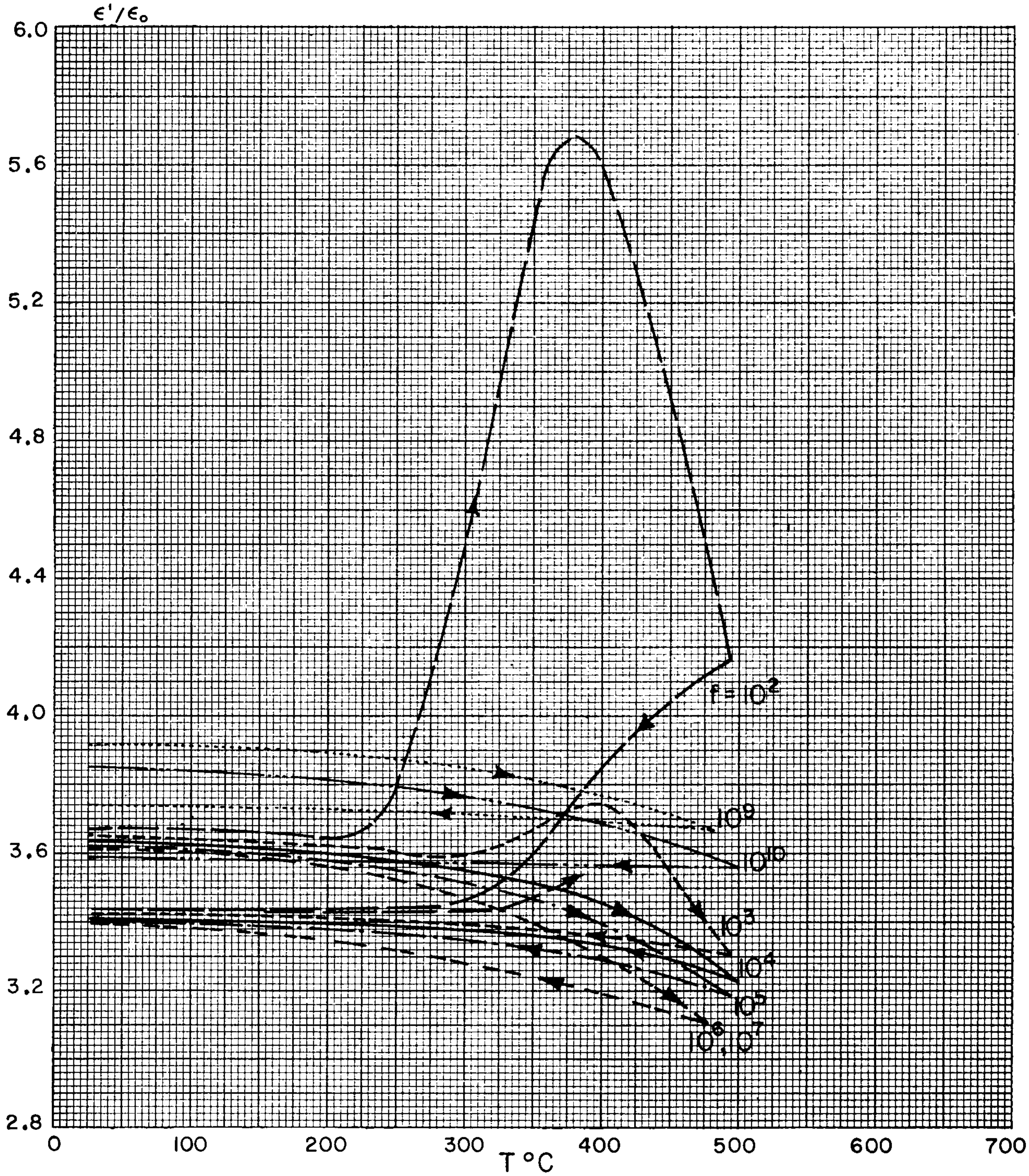
Silicone- asbestos laminate

Goodyear Aircraft Corp.



III B 5. Silicone Resins

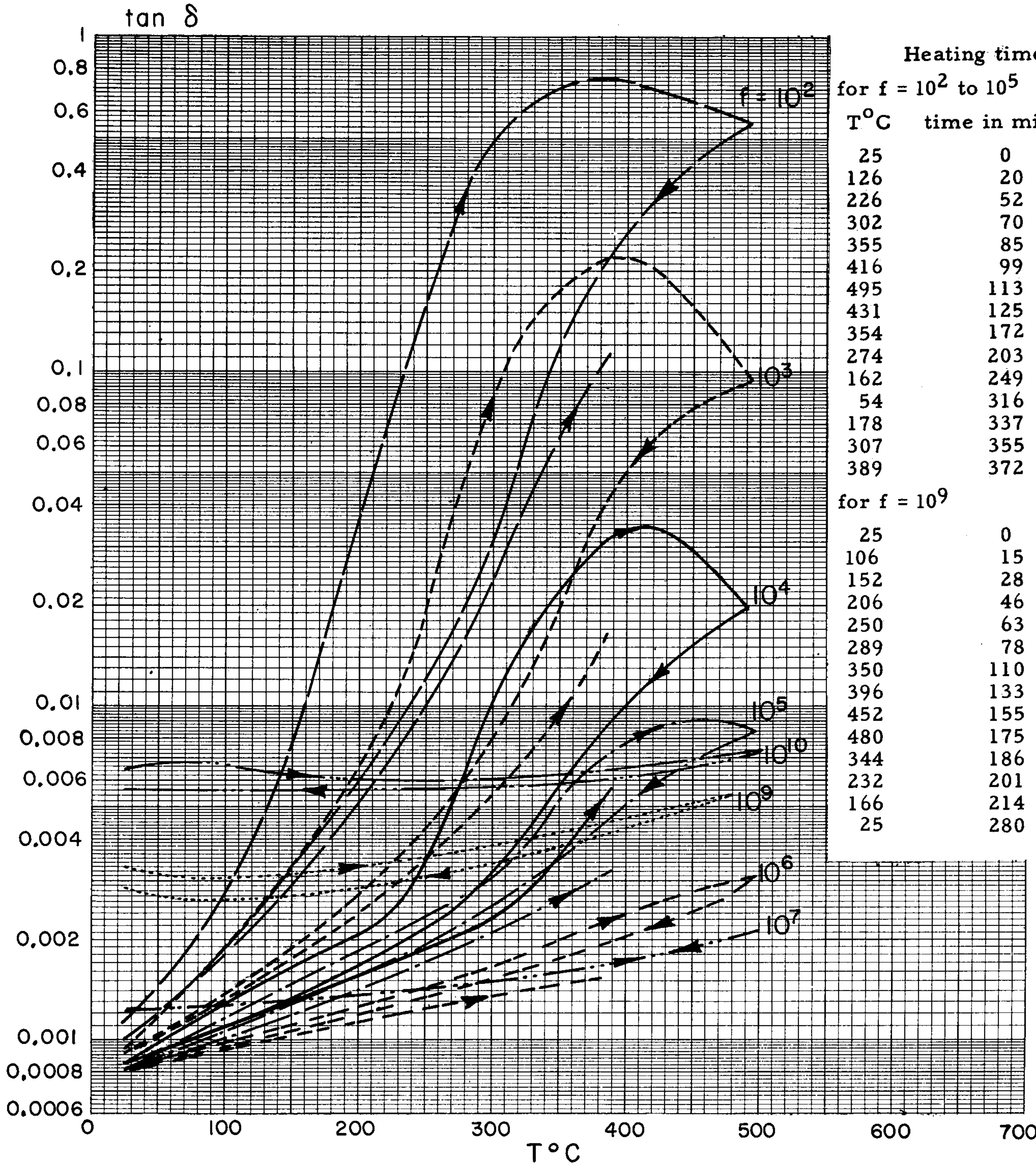
Silicone-"fiberglas" laminate, pressed Goodyear Aircraft Corp.



III B 5. Silicone Resins

Silicone-"fiberglas" laminate, pressed

Goodyear Aircraft Corp.



Heating time

for f = 10^2 to 10^5

T°C	time in minutes
25	0
126	20
226	52
302	70
355	85
416	99
495	113
431	125
354	172
274	203
162	249
54	316
178	337
307	355
389	372

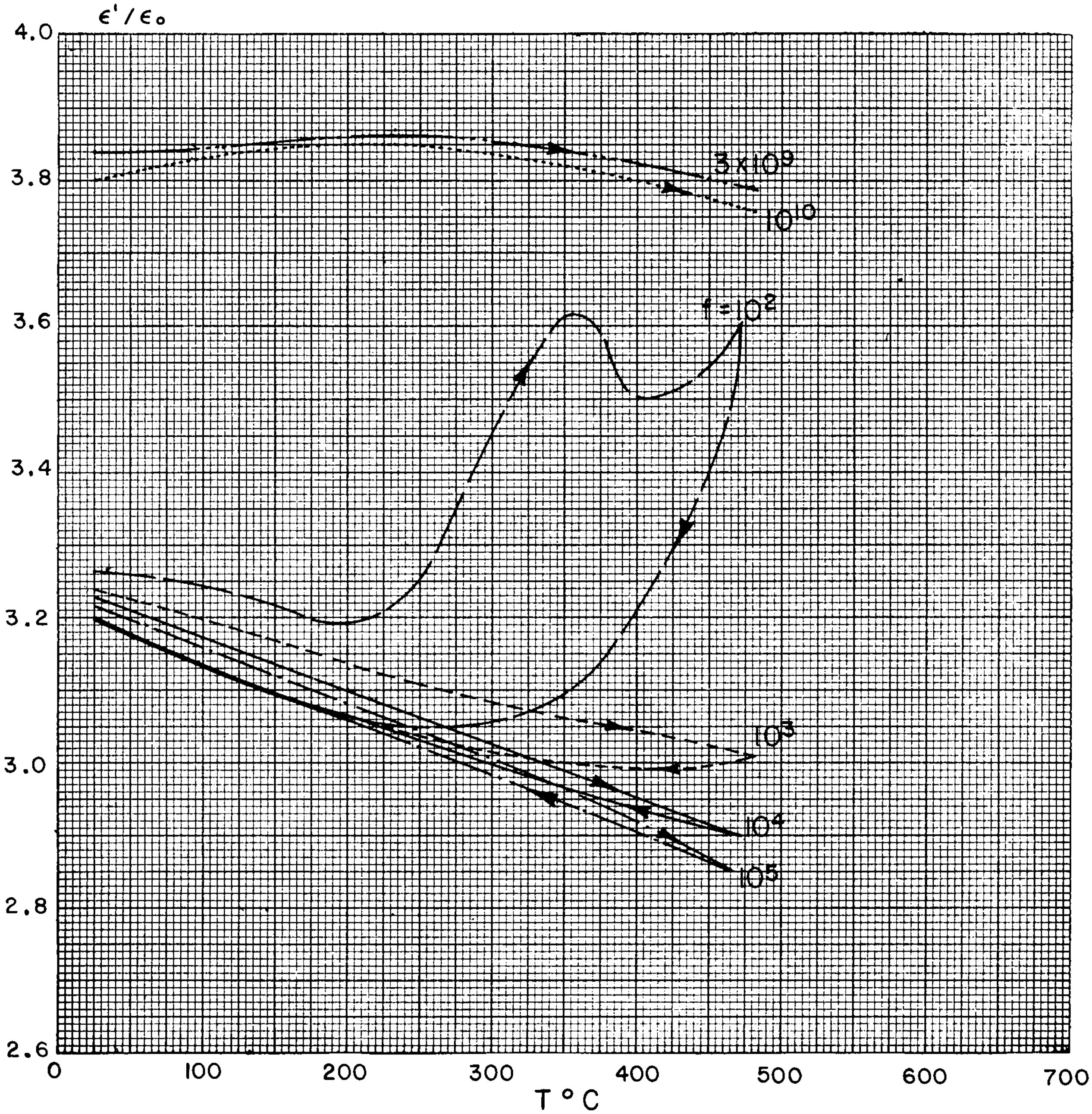
for f = 10^9

T°C	time in minutes
25	0
106	15
152	28
206	46
250	63
289	78
350	110
396	133
452	155
480	175
344	186
232	201
166	214
25	280

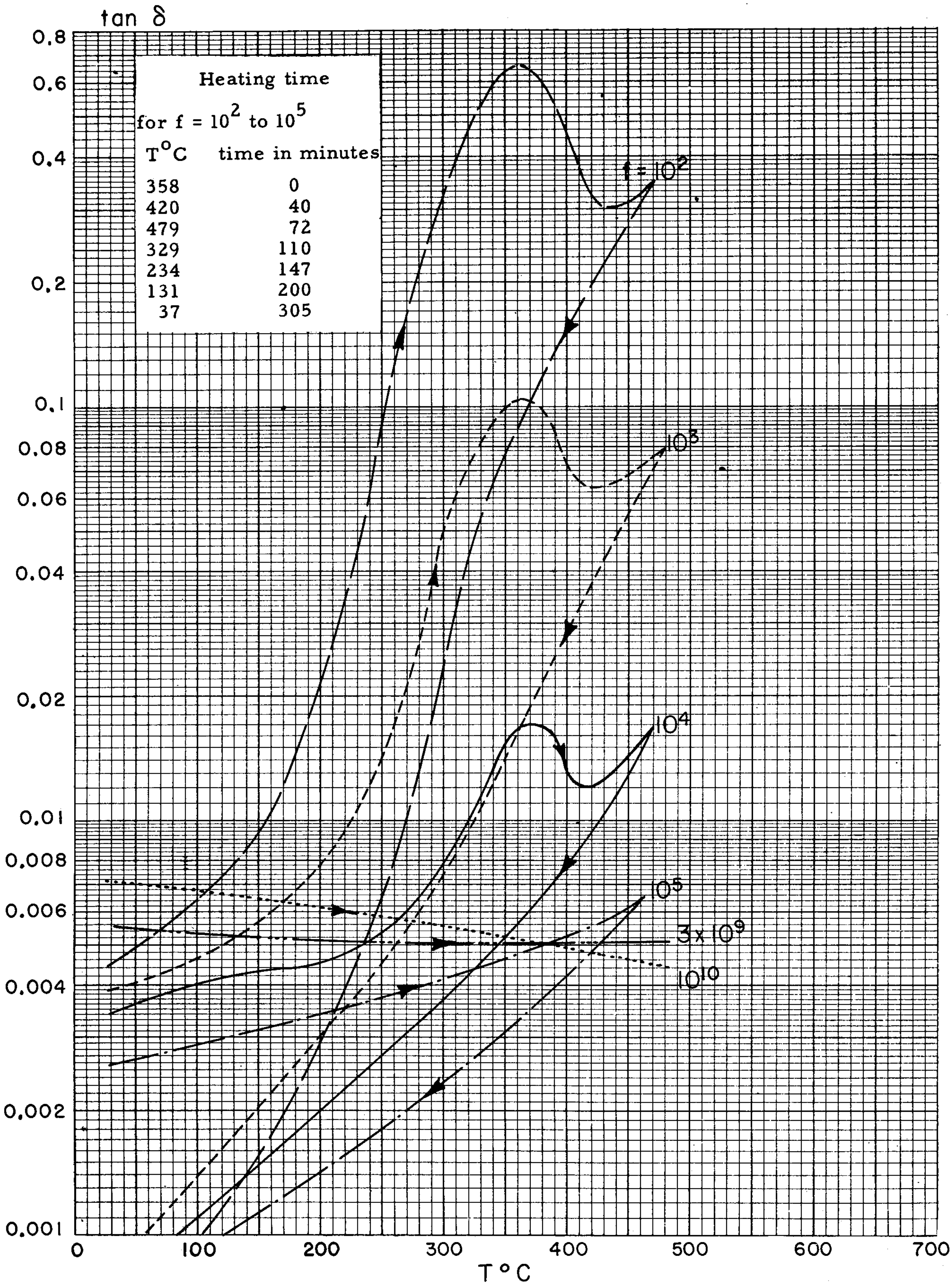
III B 5. Silicone Resins

Silicone-"fiberglas"laminate, bagged

Goodyear Aircraft Corp.



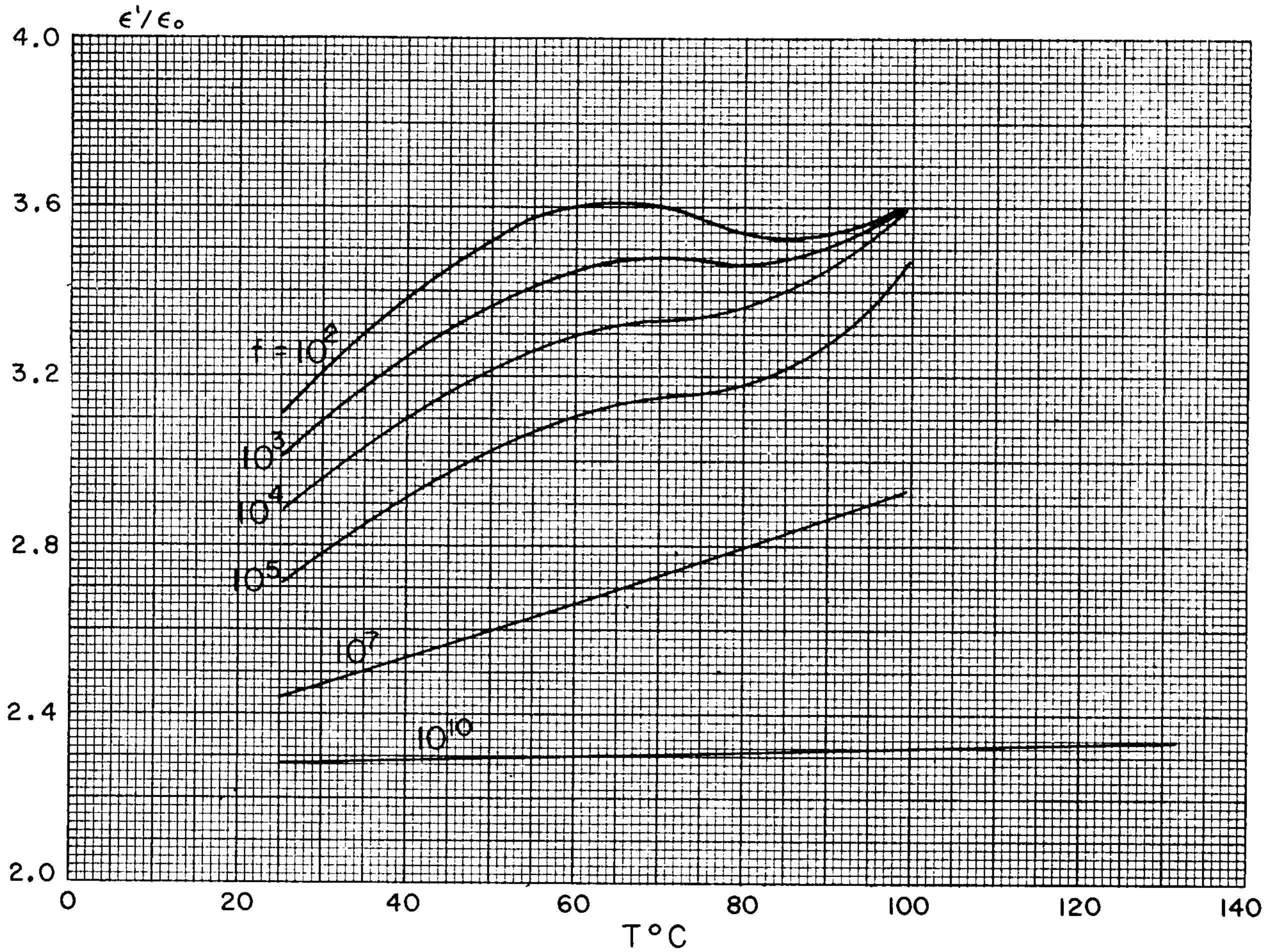
Silicone-"fiberglas"laminate, bagged Goodyear Aircraft Corp.



III B 6. Polychlorotrifluoroethylene

"Kel-F" X-200

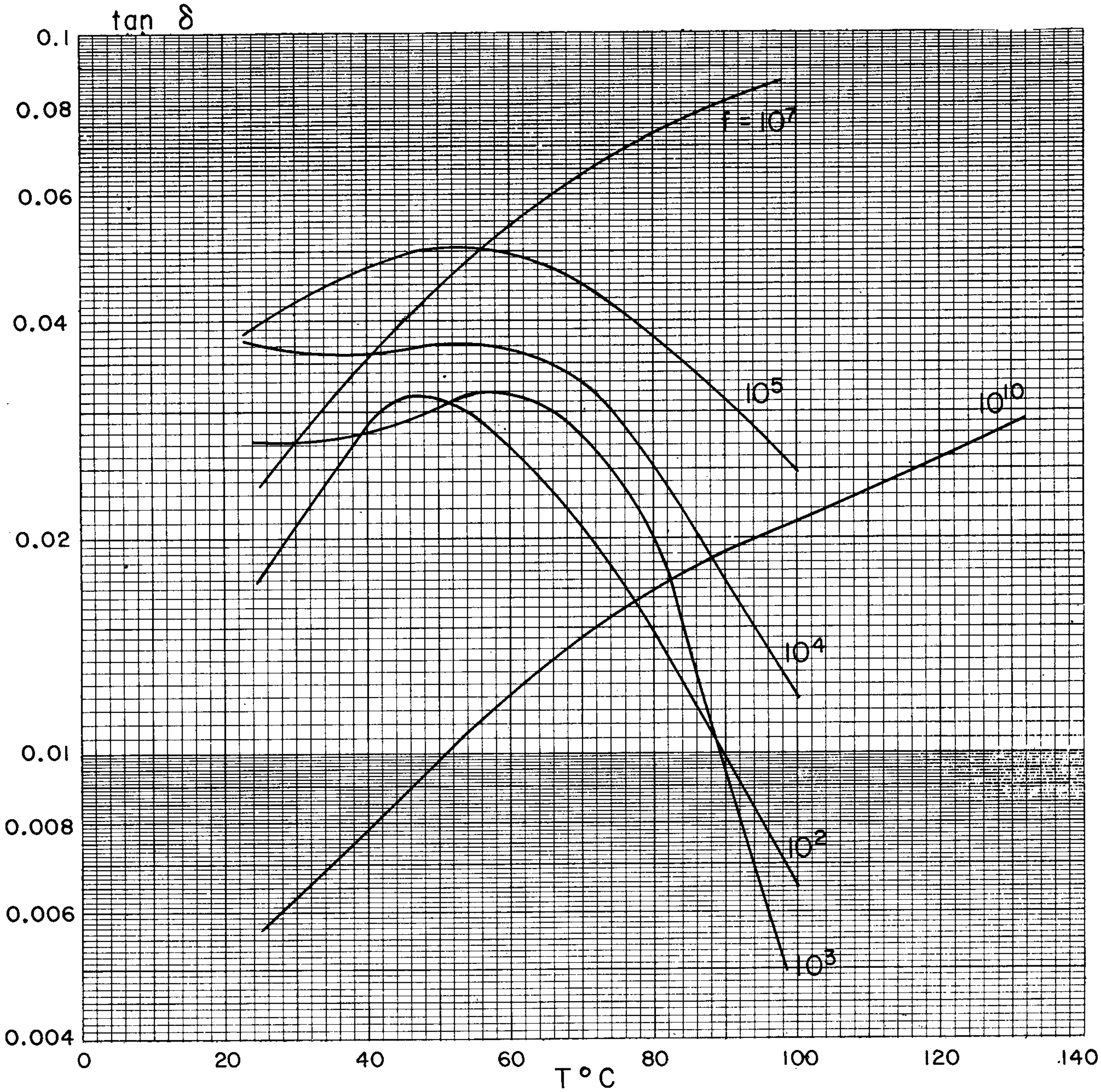
M. W. Kellogg



III B 6. Polychlorotrifluoroethylene

"Kel-F" X-200

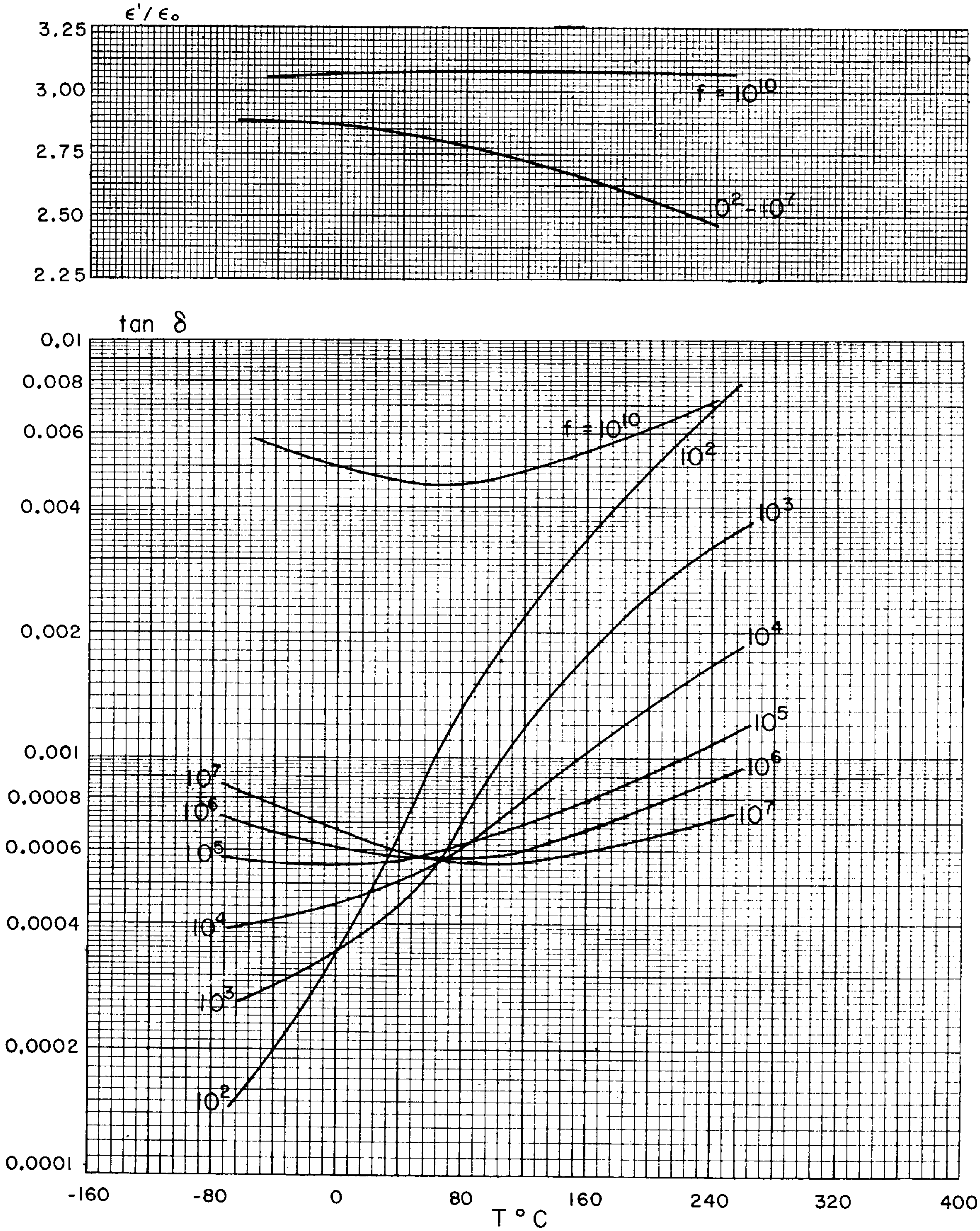
M. W. Kellogg



III B 7. Polytetrafluoroethylene

"Dilecto" ("Teflon" laminate) GB-112T

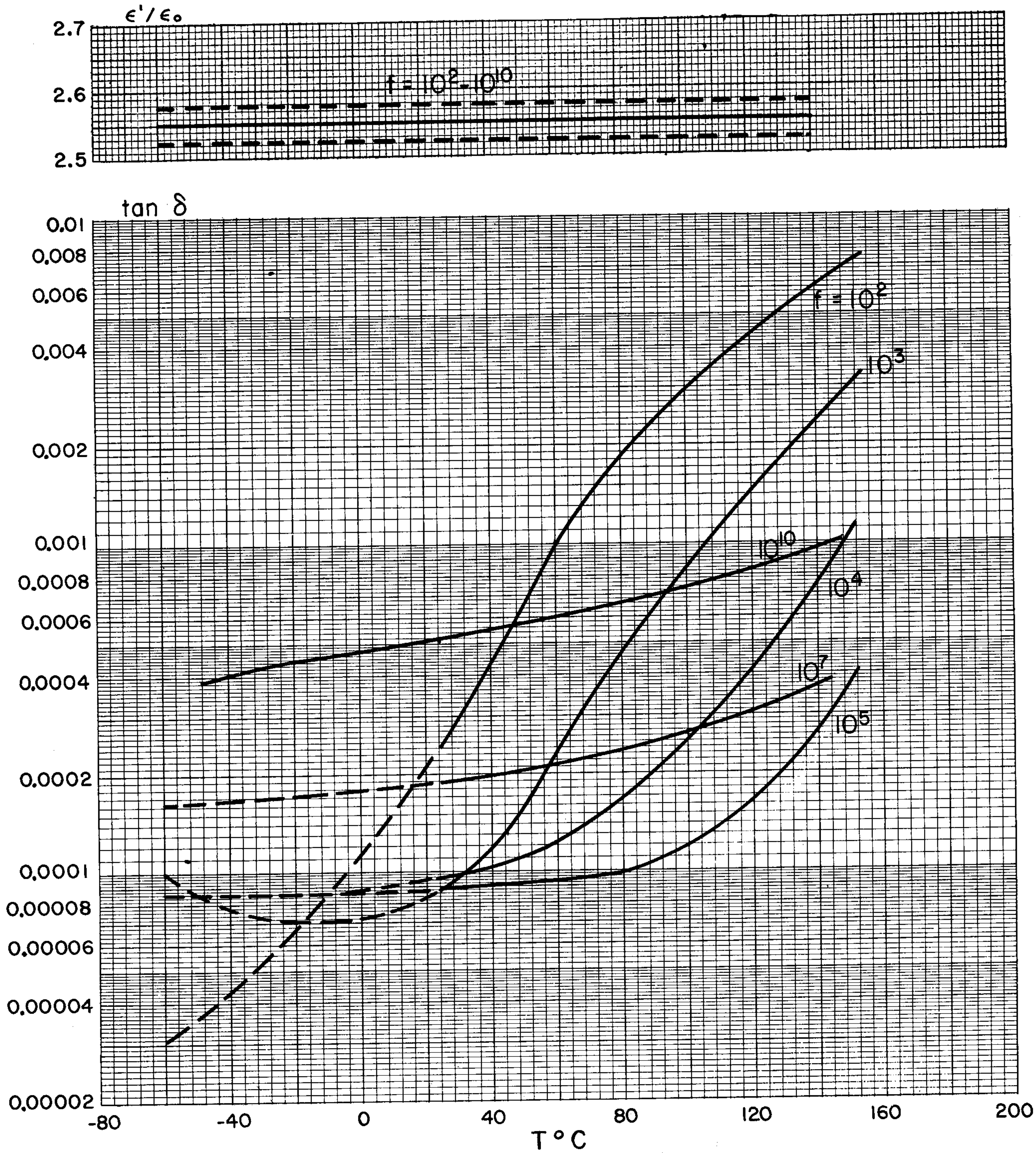
Continental Diamond



III B 8. Styrene Copolymers

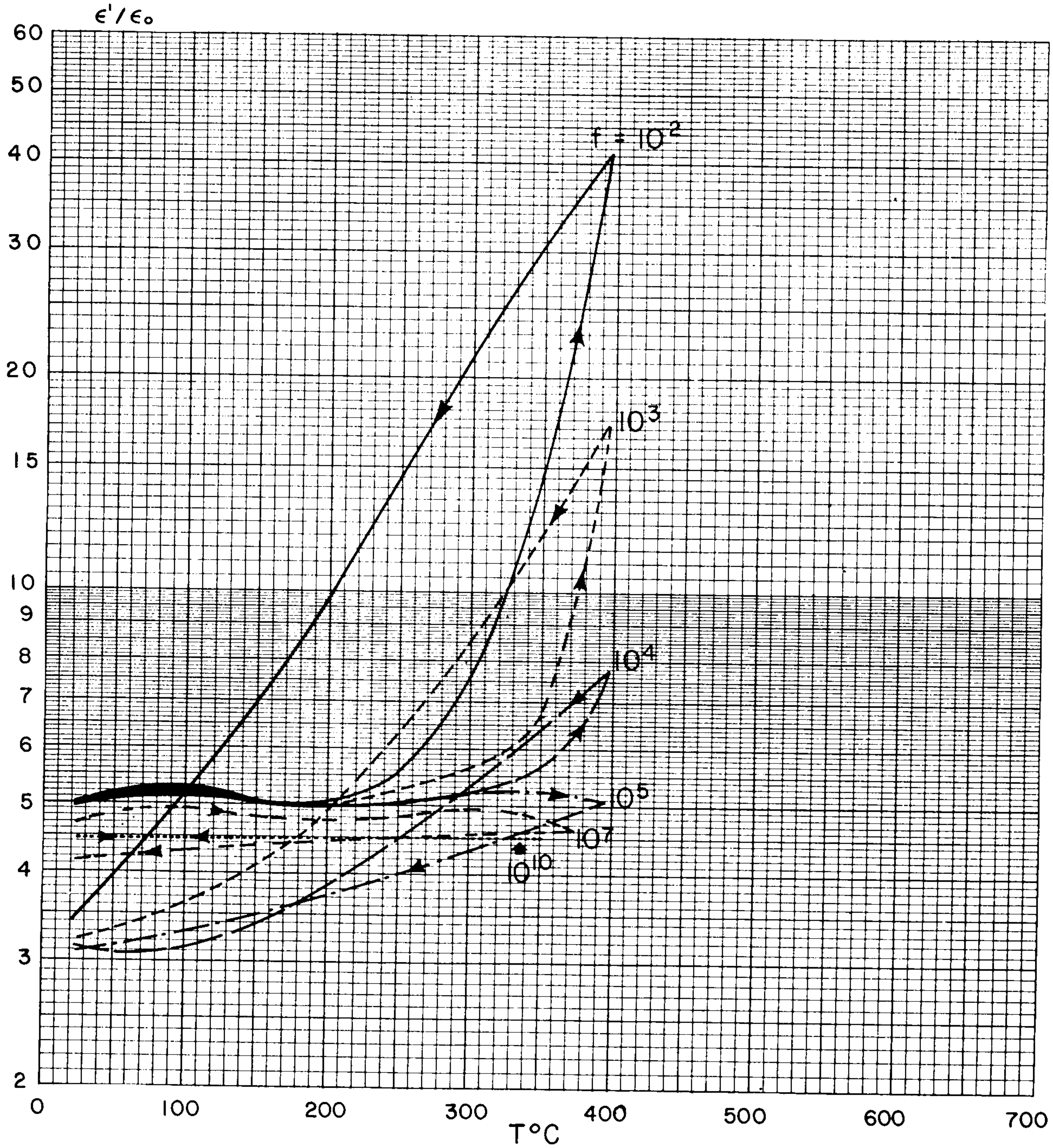
"Rexolite" 1422

Rex Plastics



"Laminac" 4232 - glass mat

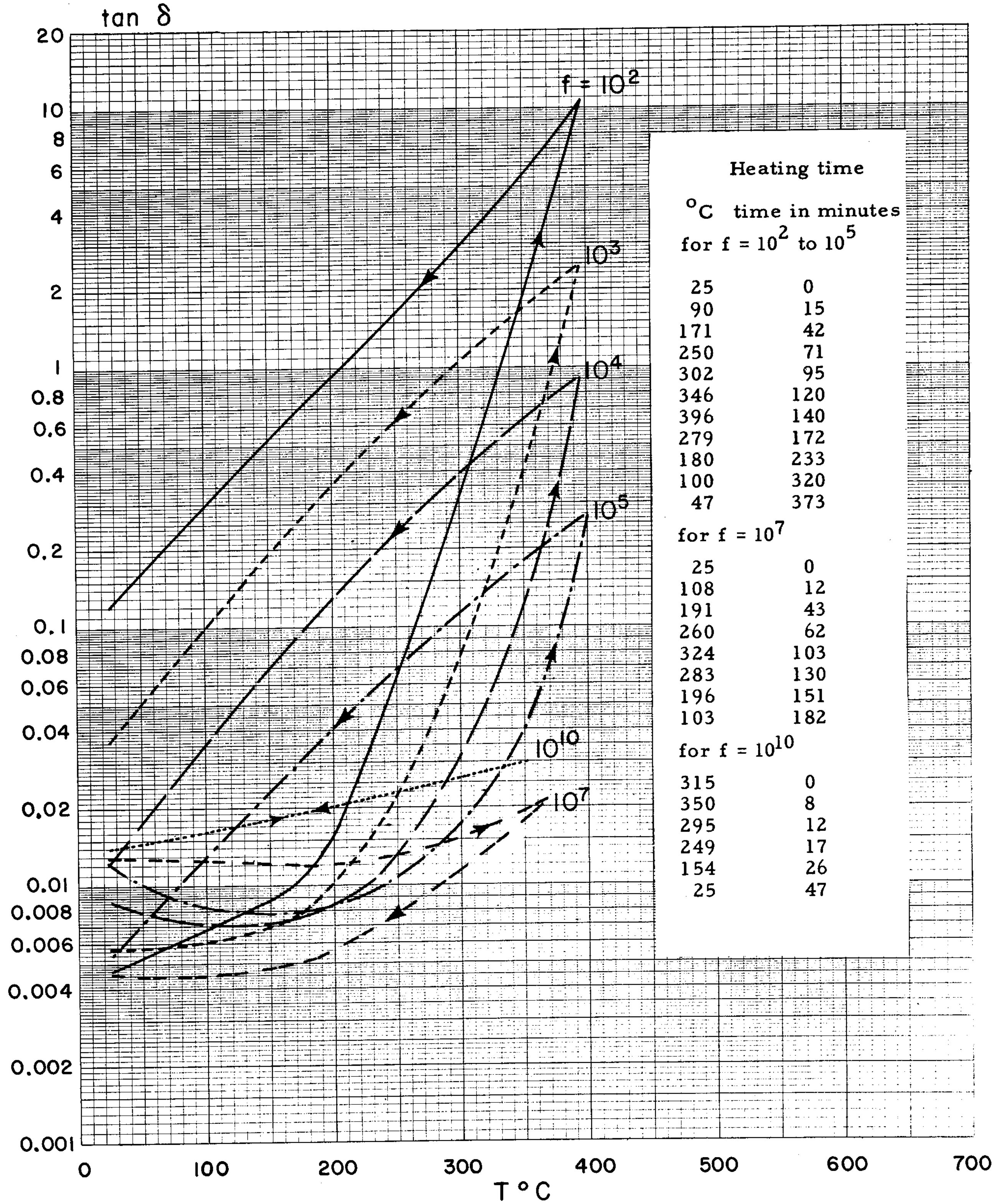
American Cyanamid



III B 9. Polyesters

"Laminac" 4232 - glass mat

American Cyanamid



Heating time

°C time in minutes

for f = 10^2 to 10^5

°C	time in minutes
25	0
90	15
171	42
250	71
302	95
346	120
396	140
279	172
180	233
100	320
47	373

for f = 10^7

°C	time in minutes
25	0
108	12
191	43
260	62
324	103
283	130
196	151
103	182

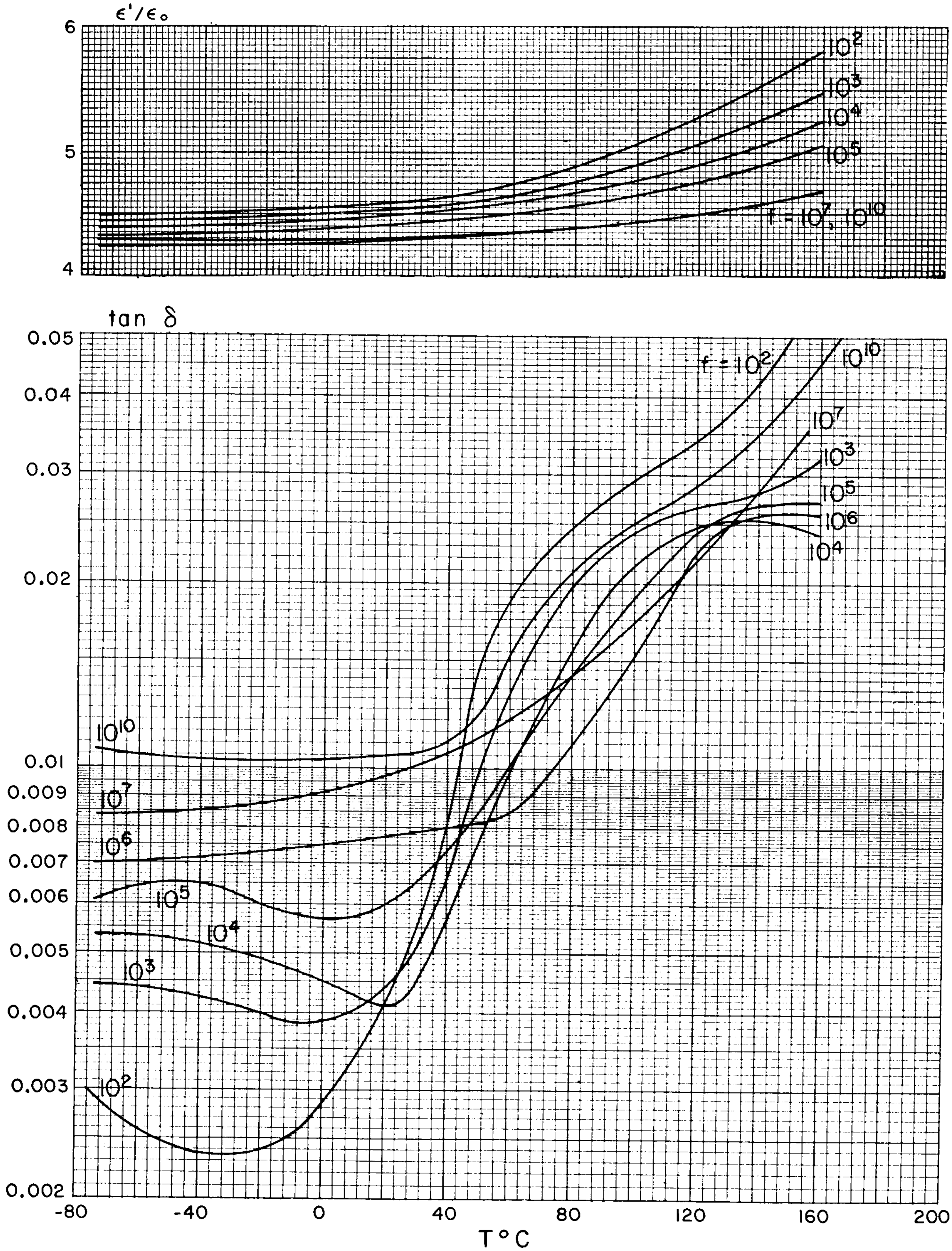
for f = 10^{10}

°C	time in minutes
315	0
350	8
295	12
249	17
154	26
25	47

III B 9. Polyesters

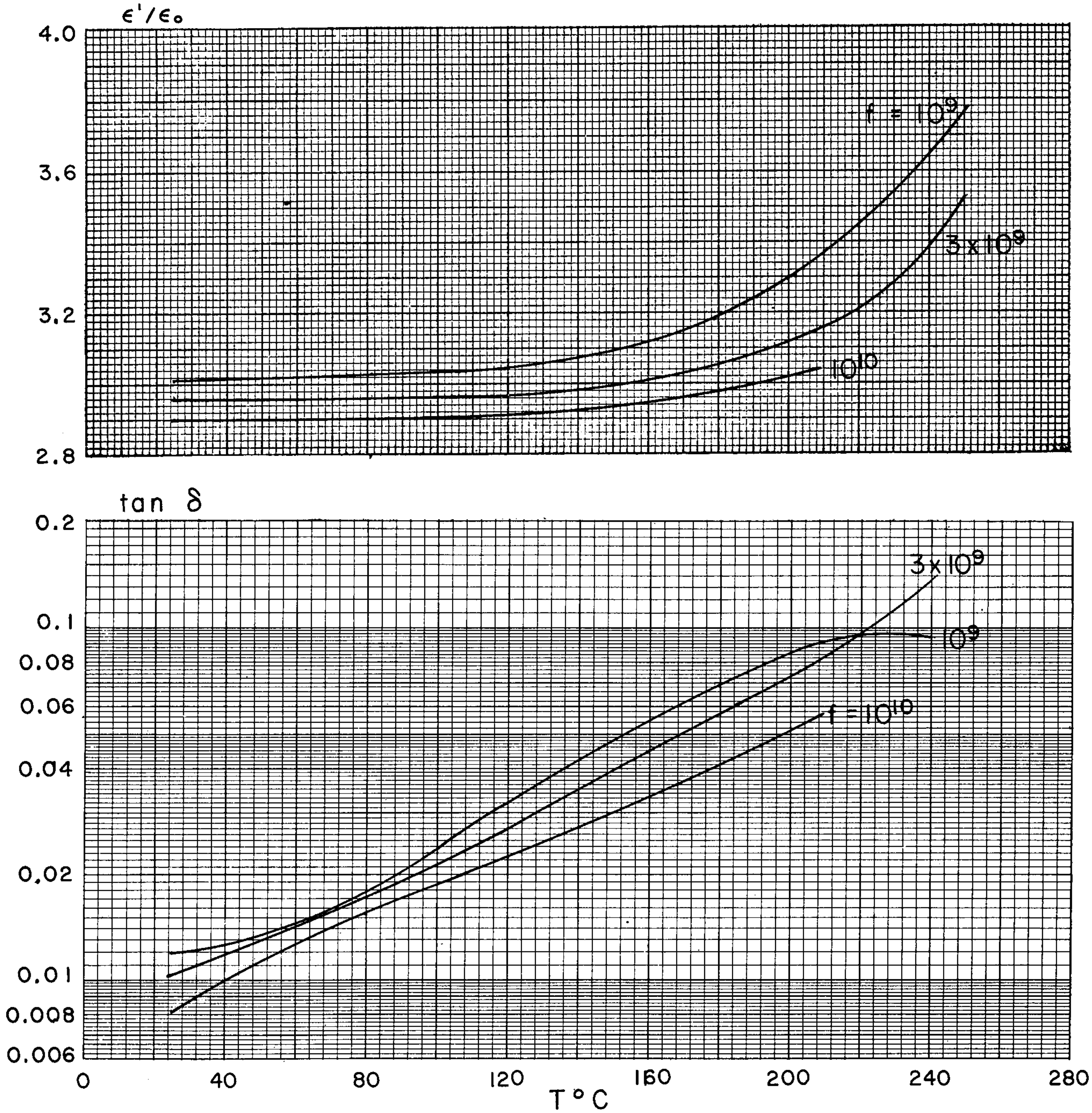
"Dilecto" GM-PE

Continental Diamond



III B 9. Polyesters

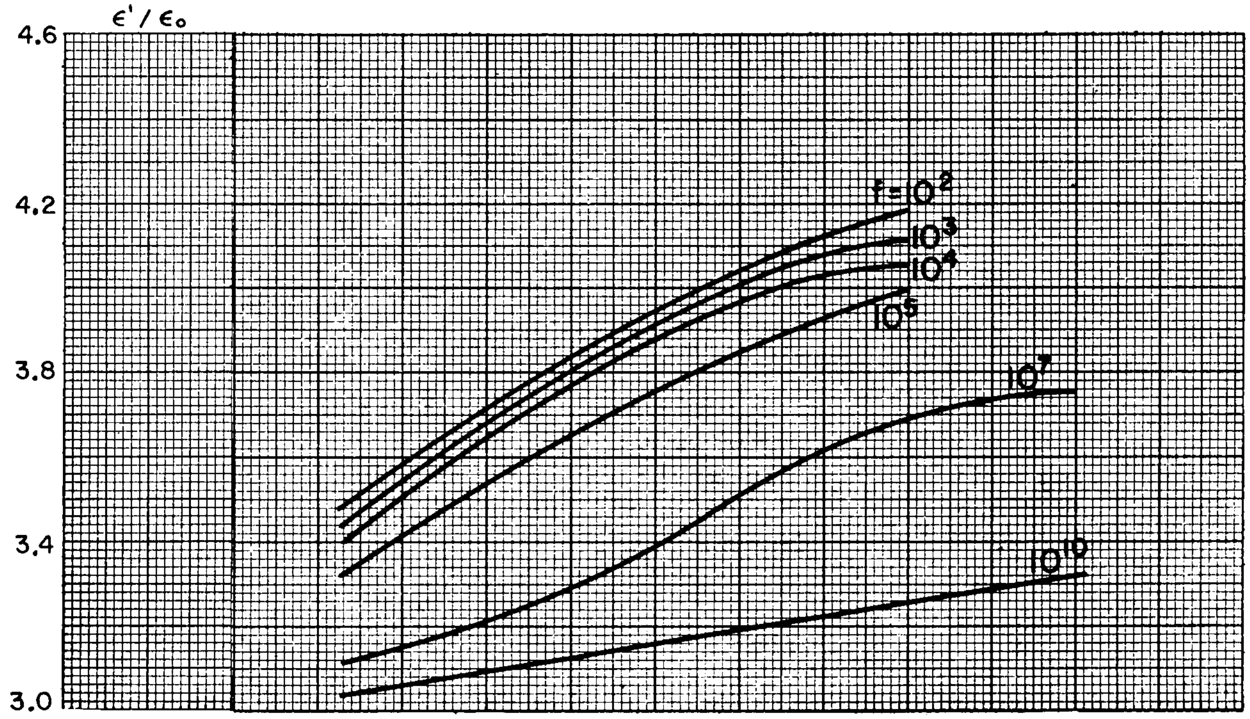
"Cronar" du Pont photo products dept.

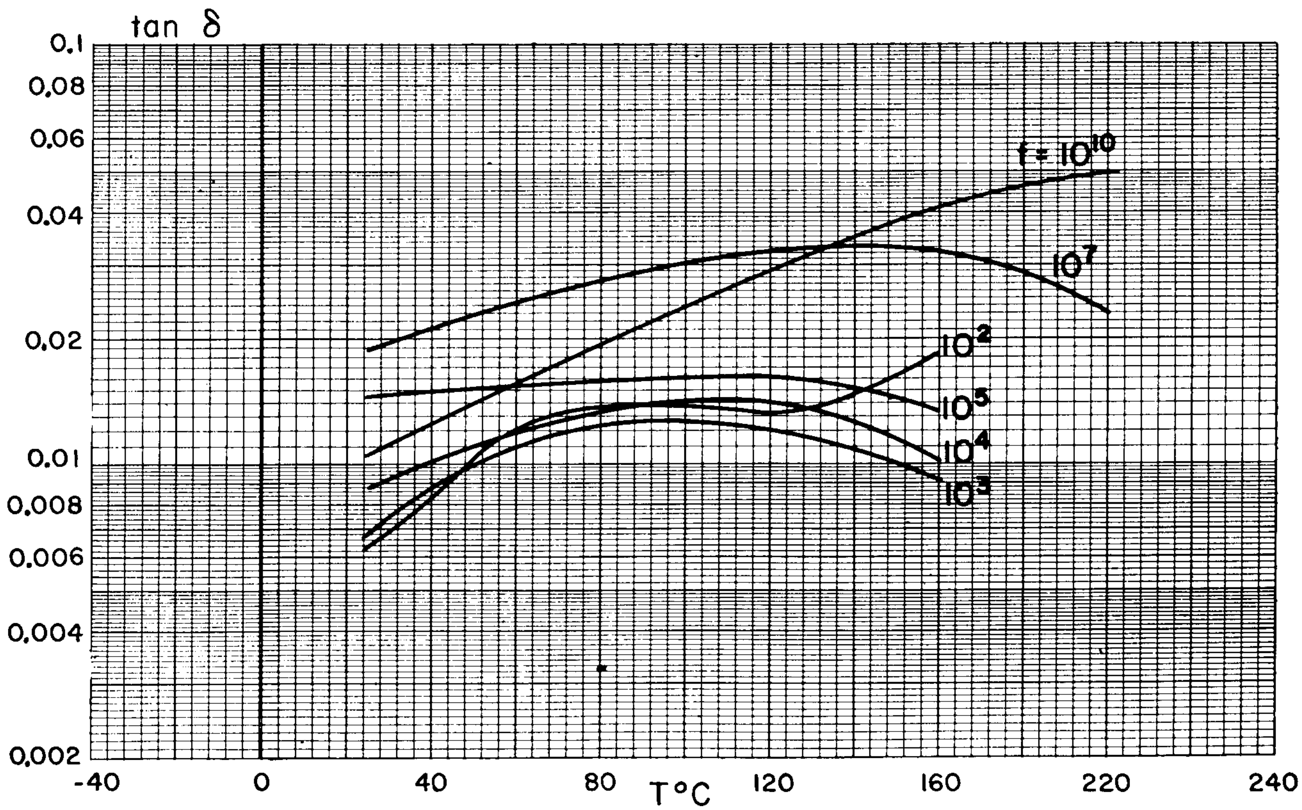


III B 9. Polyesters

"Dacron" Batt - "Stypol" 16B

du Pont

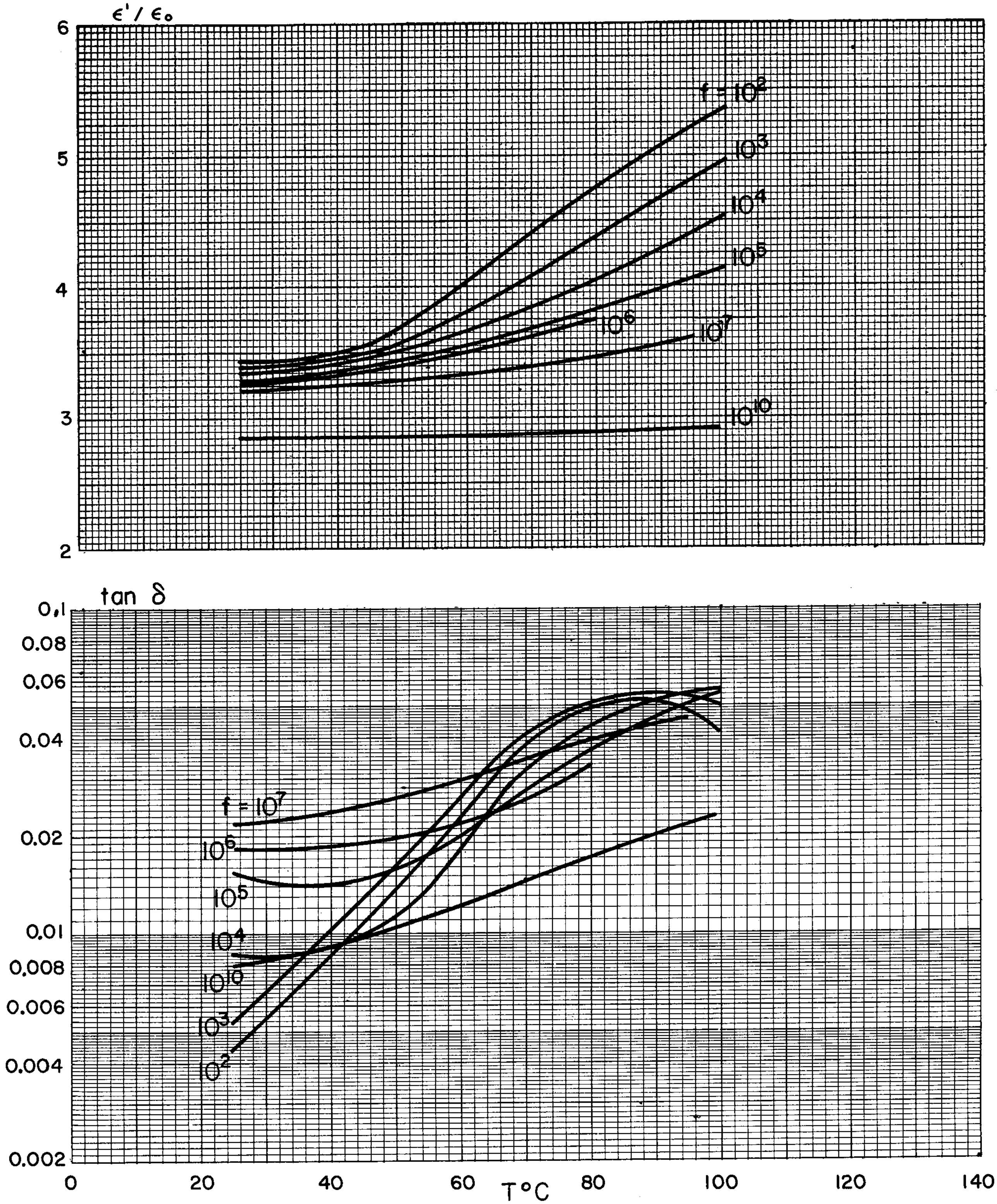




III B 9. Polyesters

"Paraplex"P43

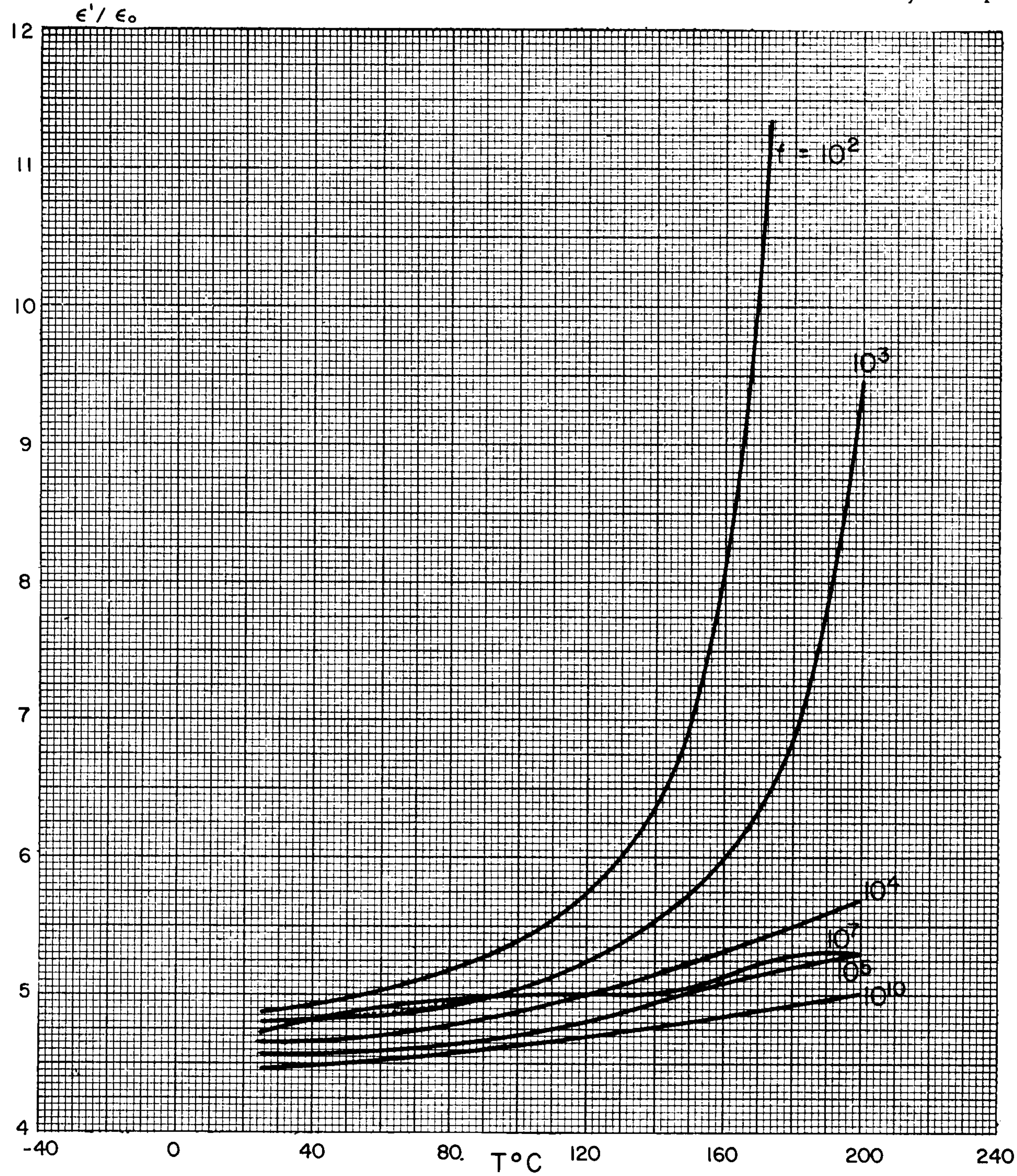
Rohm and Haas



III B 10. Alkyd Resins

"Plaskon" Alkyd Special Electrical Granular

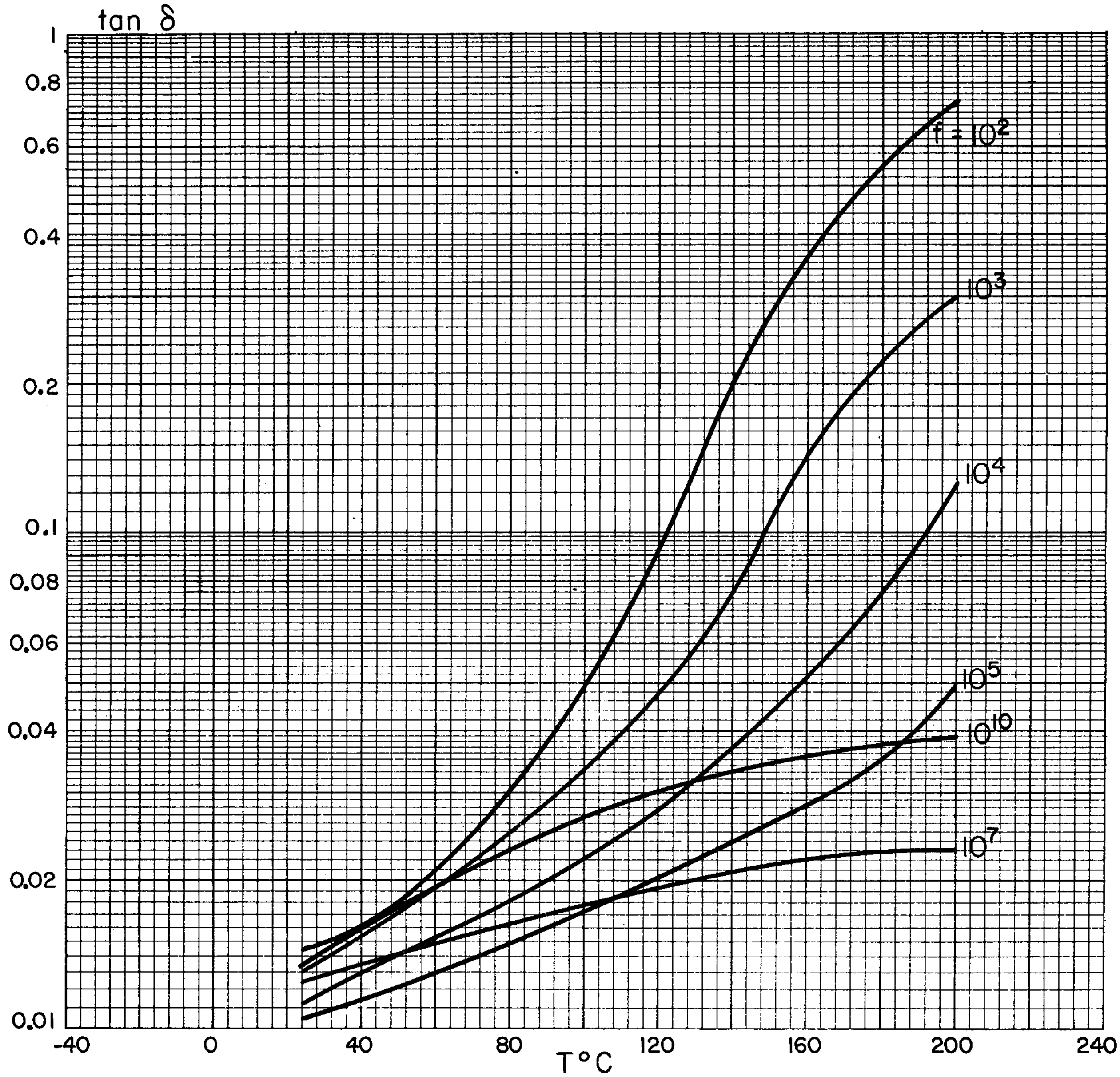
Plaskon Division
Allied Chemical and Dye Corp.



III B 10. Alkyd Resins

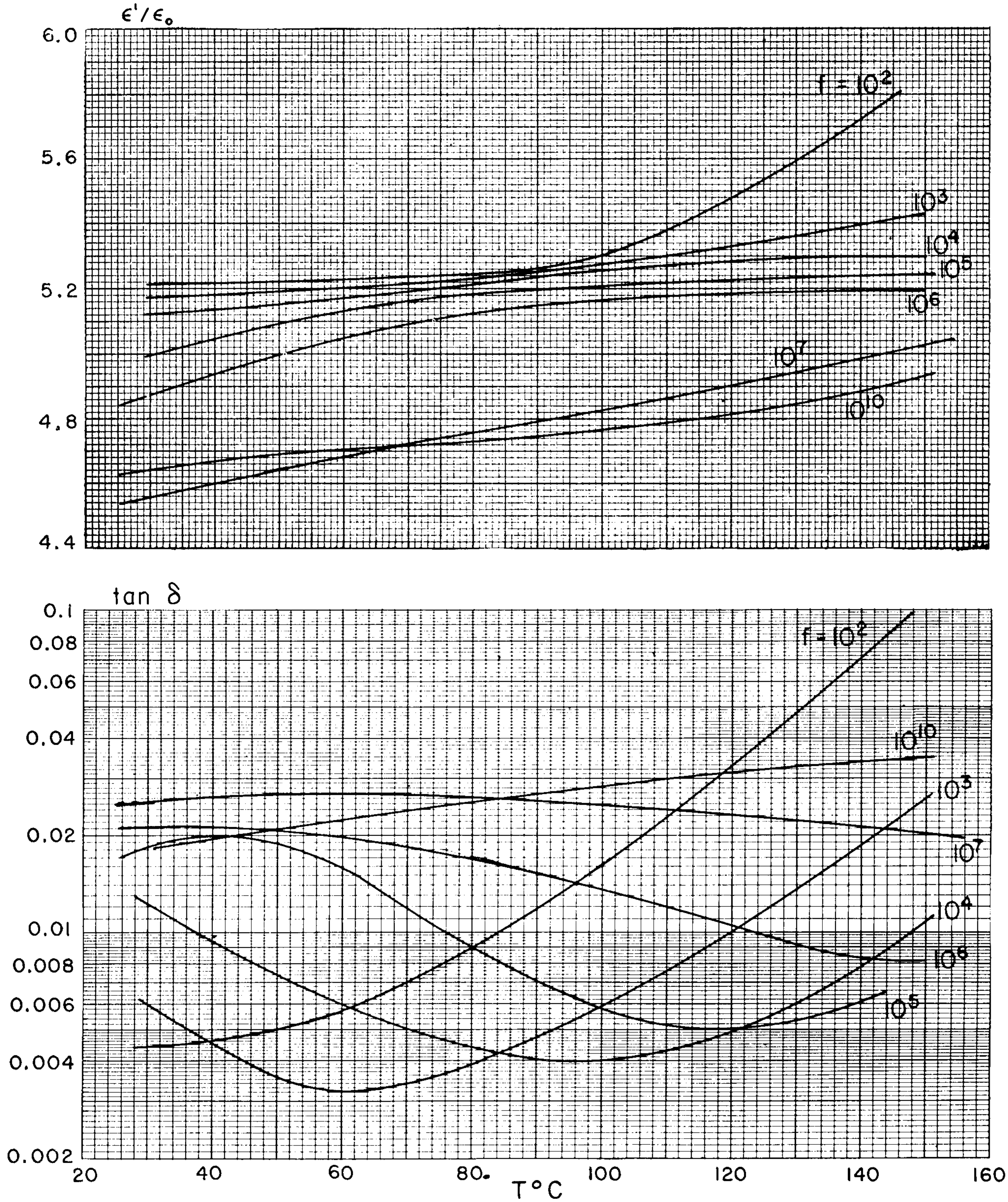
"Plaskon" Alkyd Special Electrical Granular

Plaskon Division
Allied Chemical and Dye Corp.



III B 11. Epoxy Resins

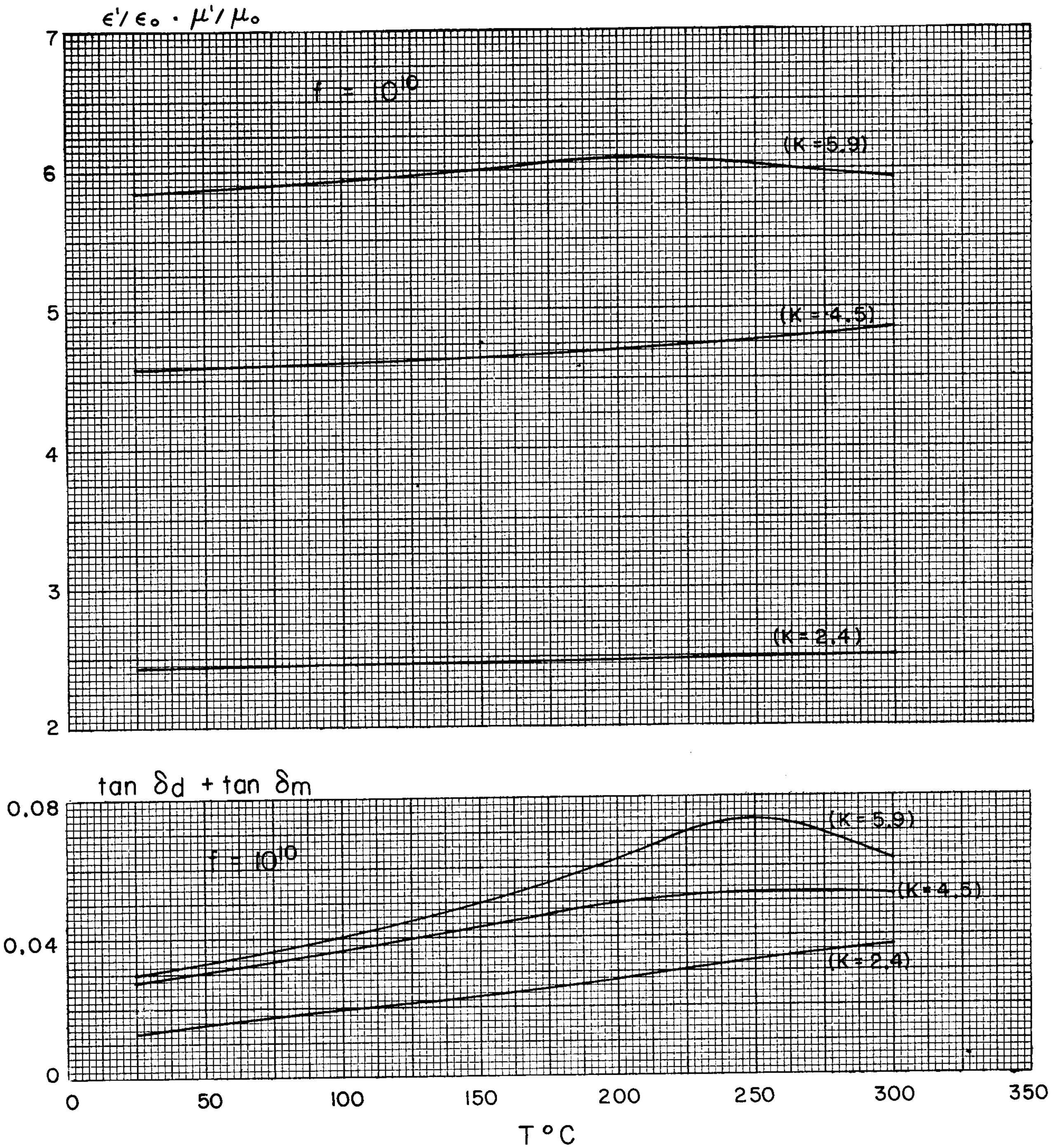
"Dilecto" (Epoxy-glass laminate) GB-181-E Continental Diamond



III B 11. Epoxy Resins

"Eccofoam" HiK (500^{o}F)
(K=5.9, K=4.5, K=2.4)

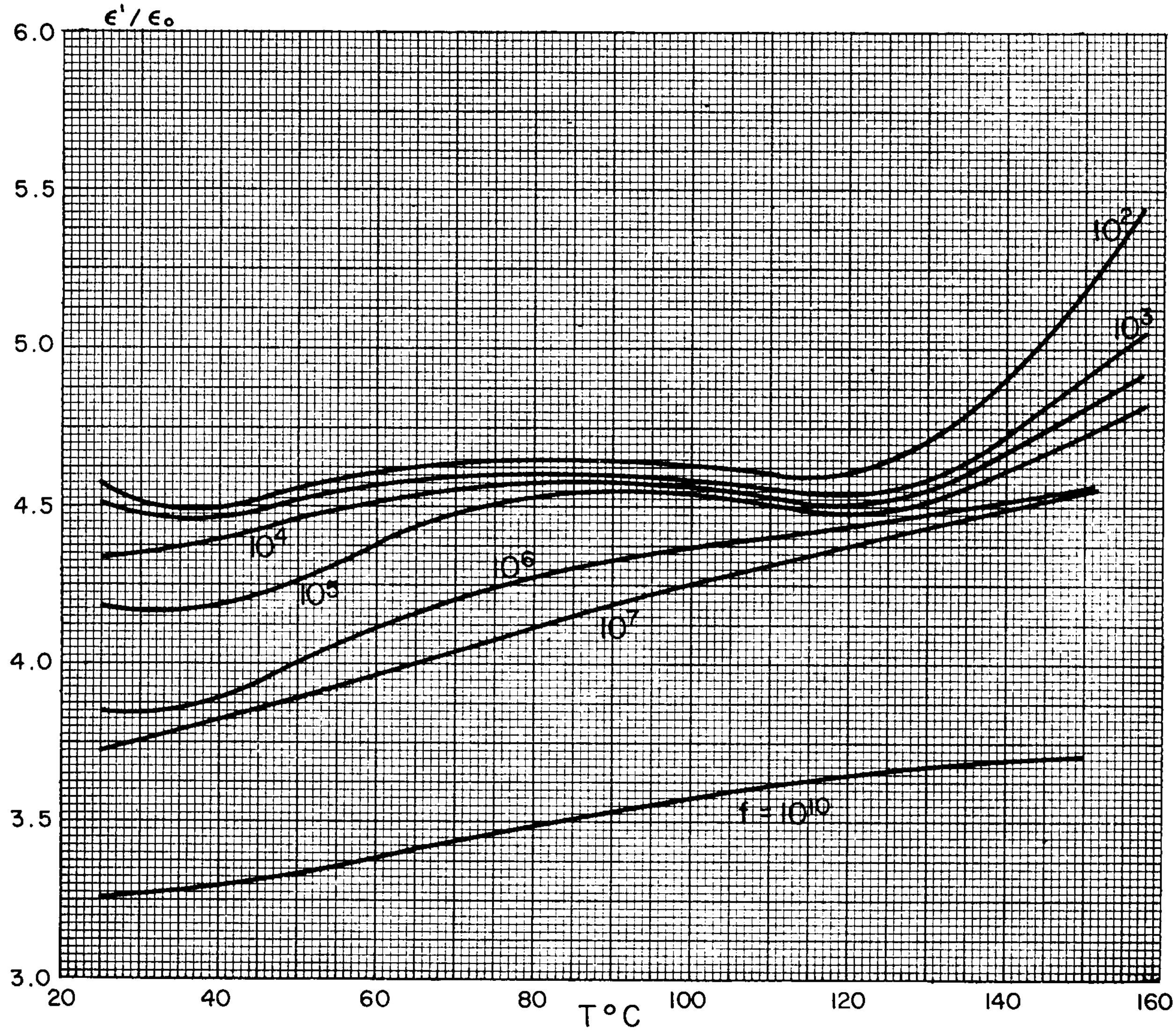
Emerson and Cuming



III B 11. Epoxy Resins

"Epon" 828 with curing agent CL

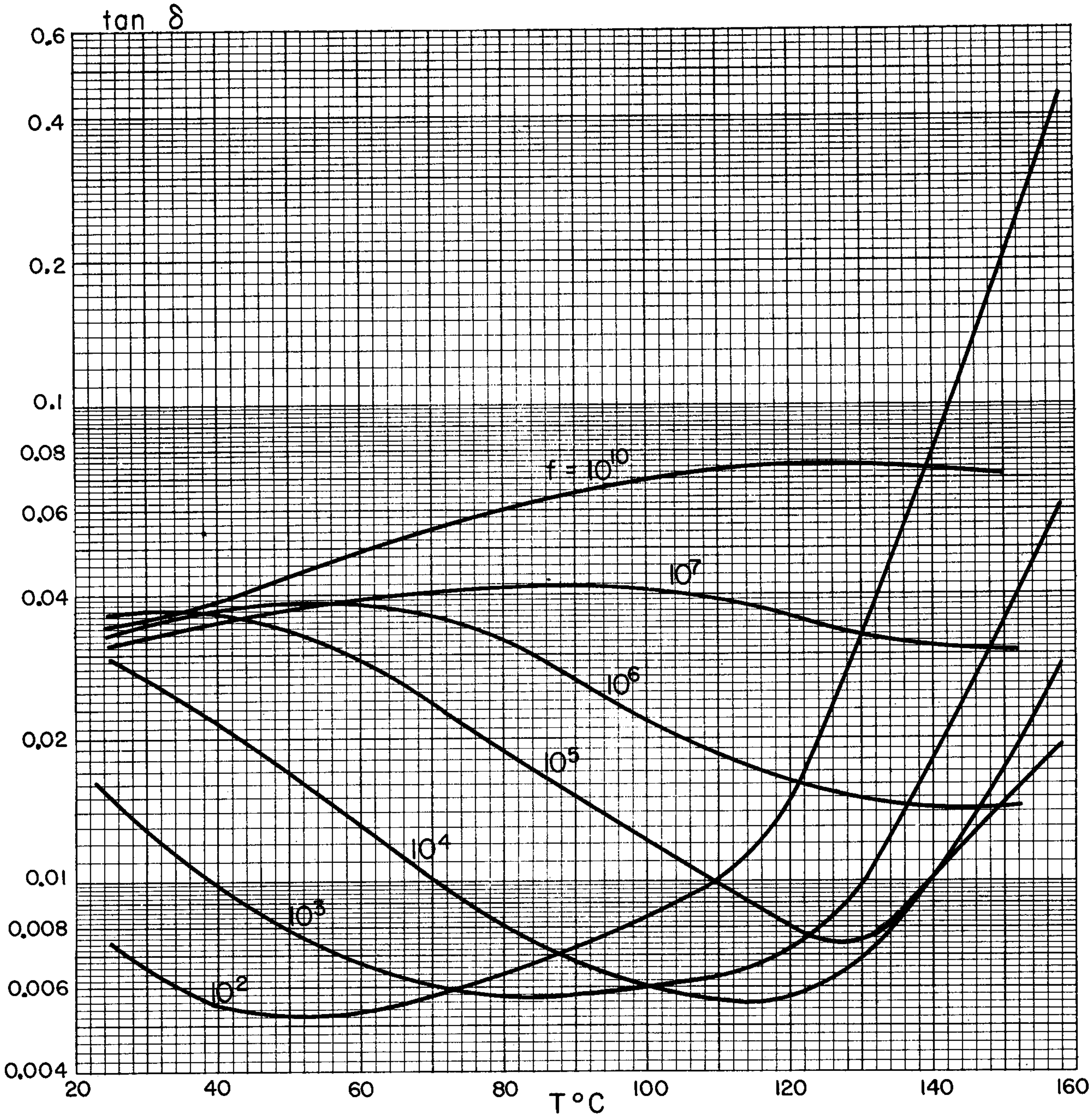
Shell Chemical



III B 11. Epoxy Resins

"Epon" 828 with curing agent CL

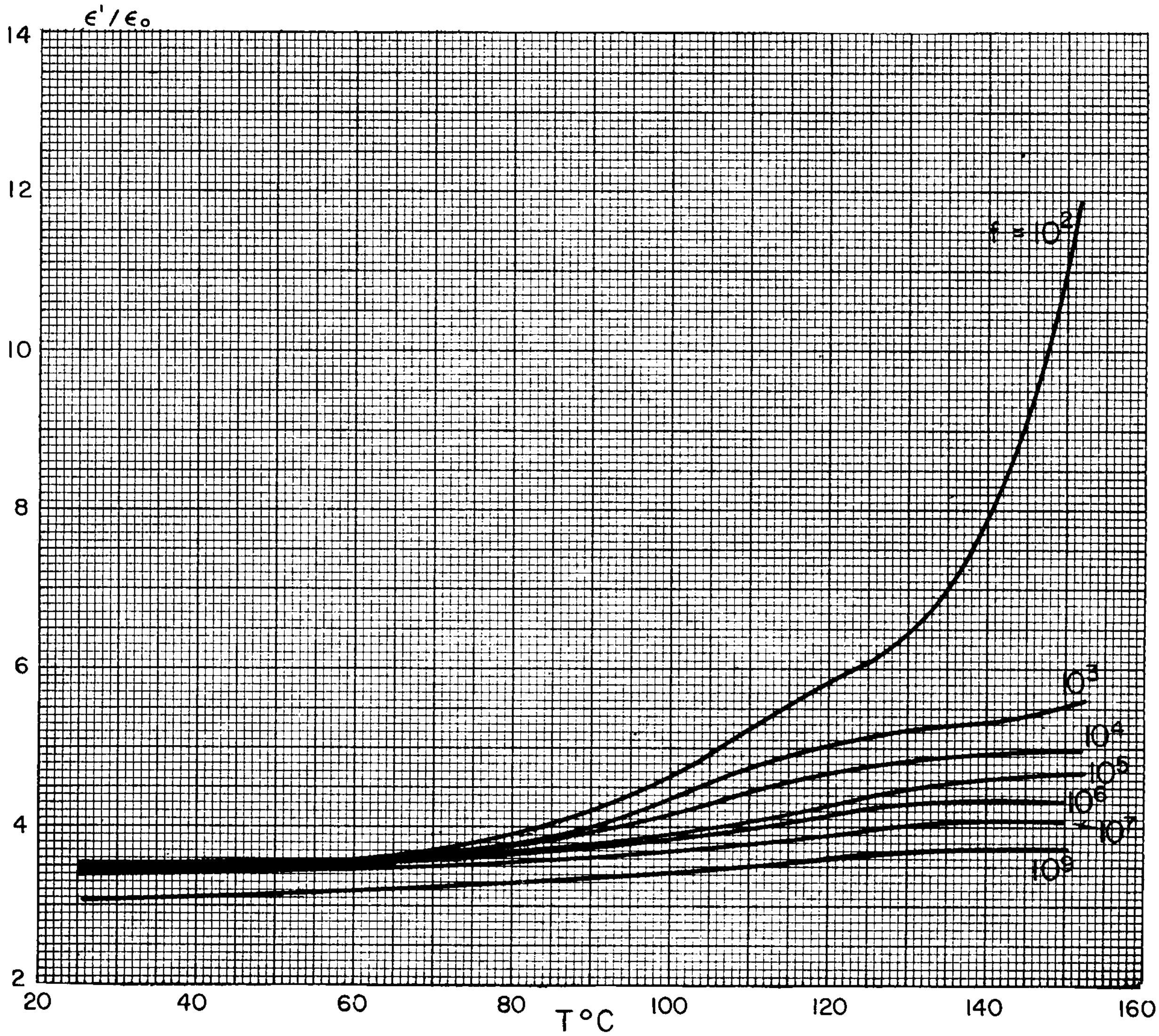
Shell Chemical



III B 11. Epoxy Resins

"Epon" 828 with curing agent D

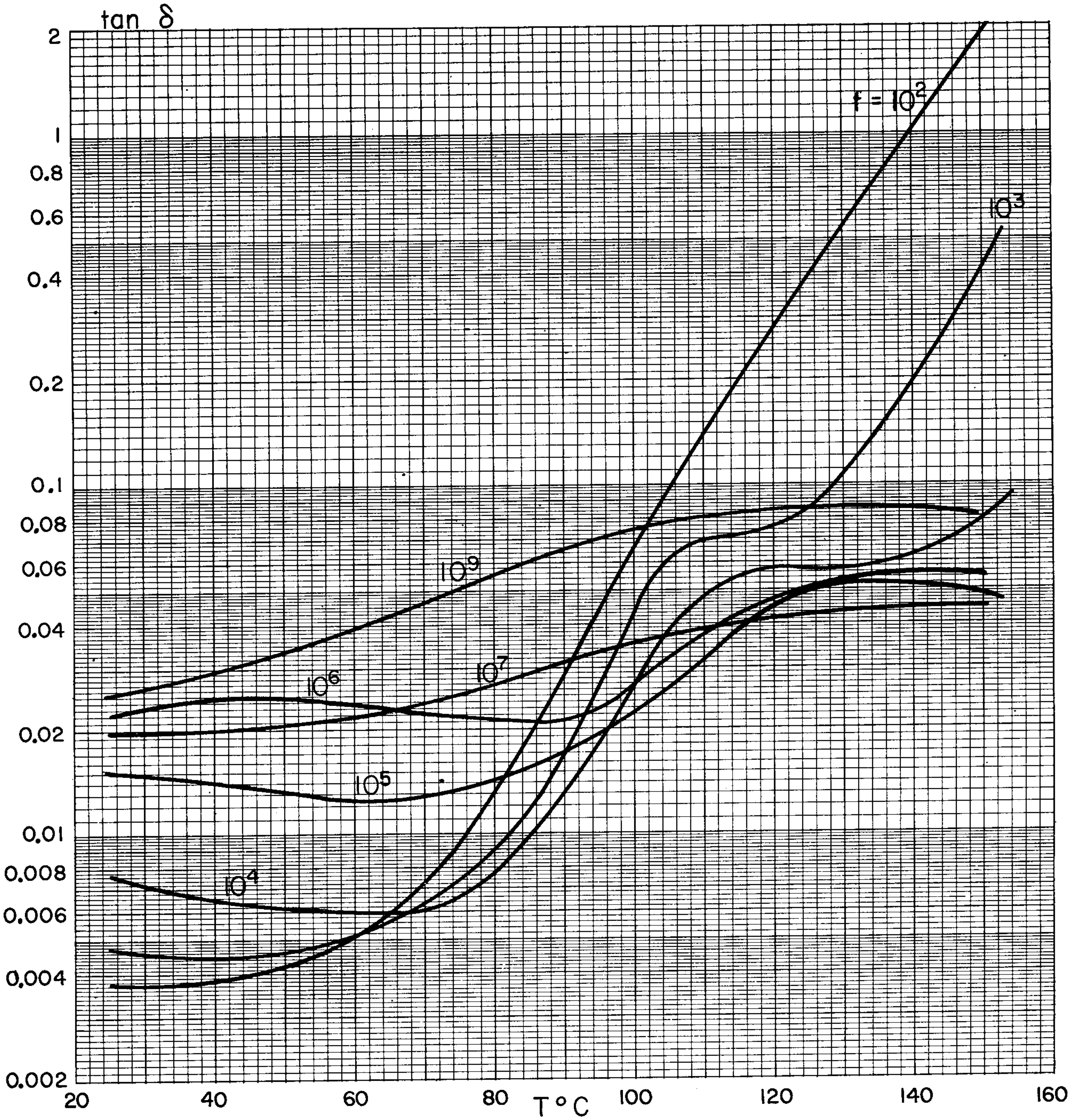
Shell Chemical



III B 11. Epoxy Resins

"Epon" 828 with curing agent D

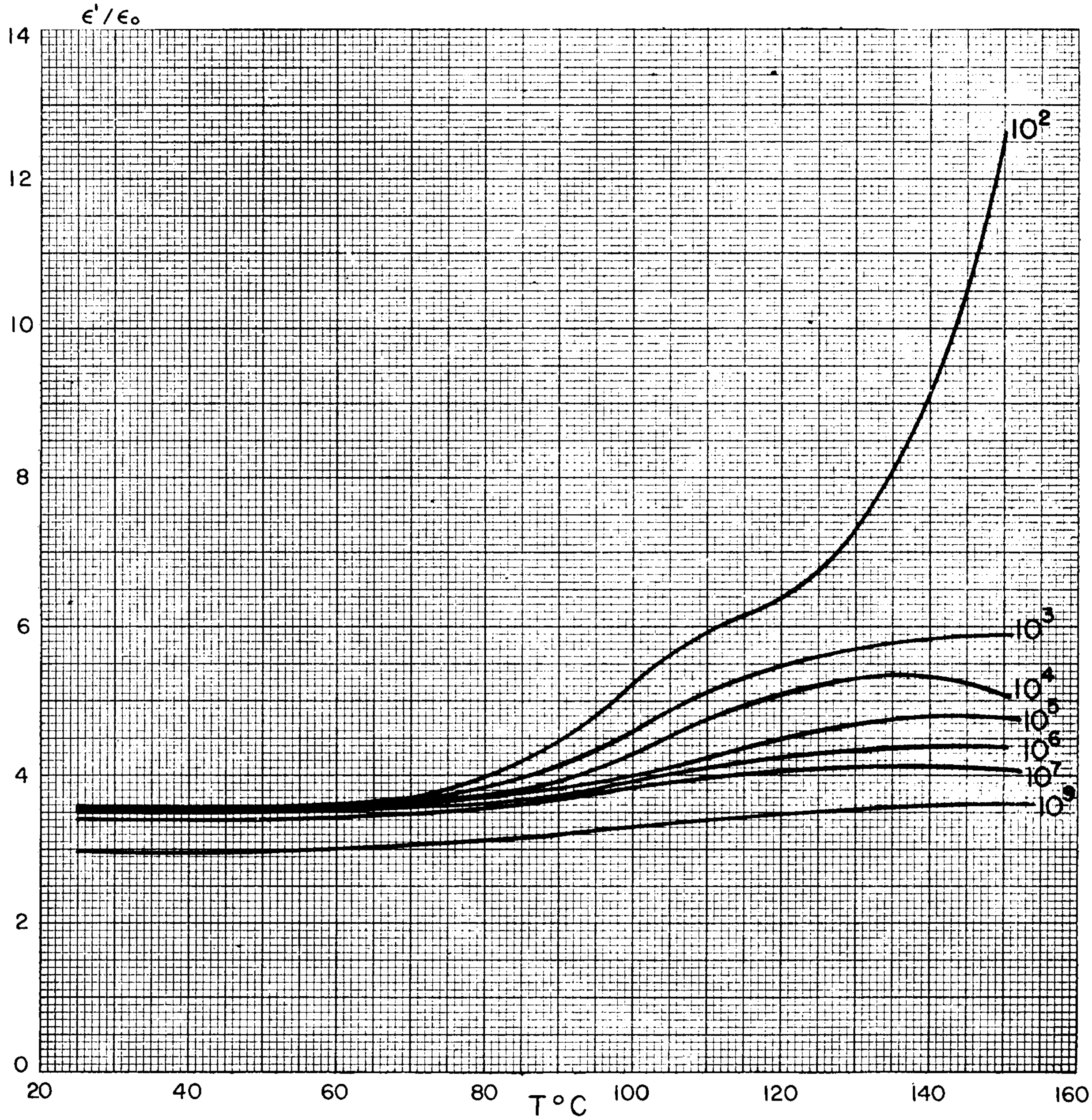
Shell Chemical



III B 11. Epoxy Resins

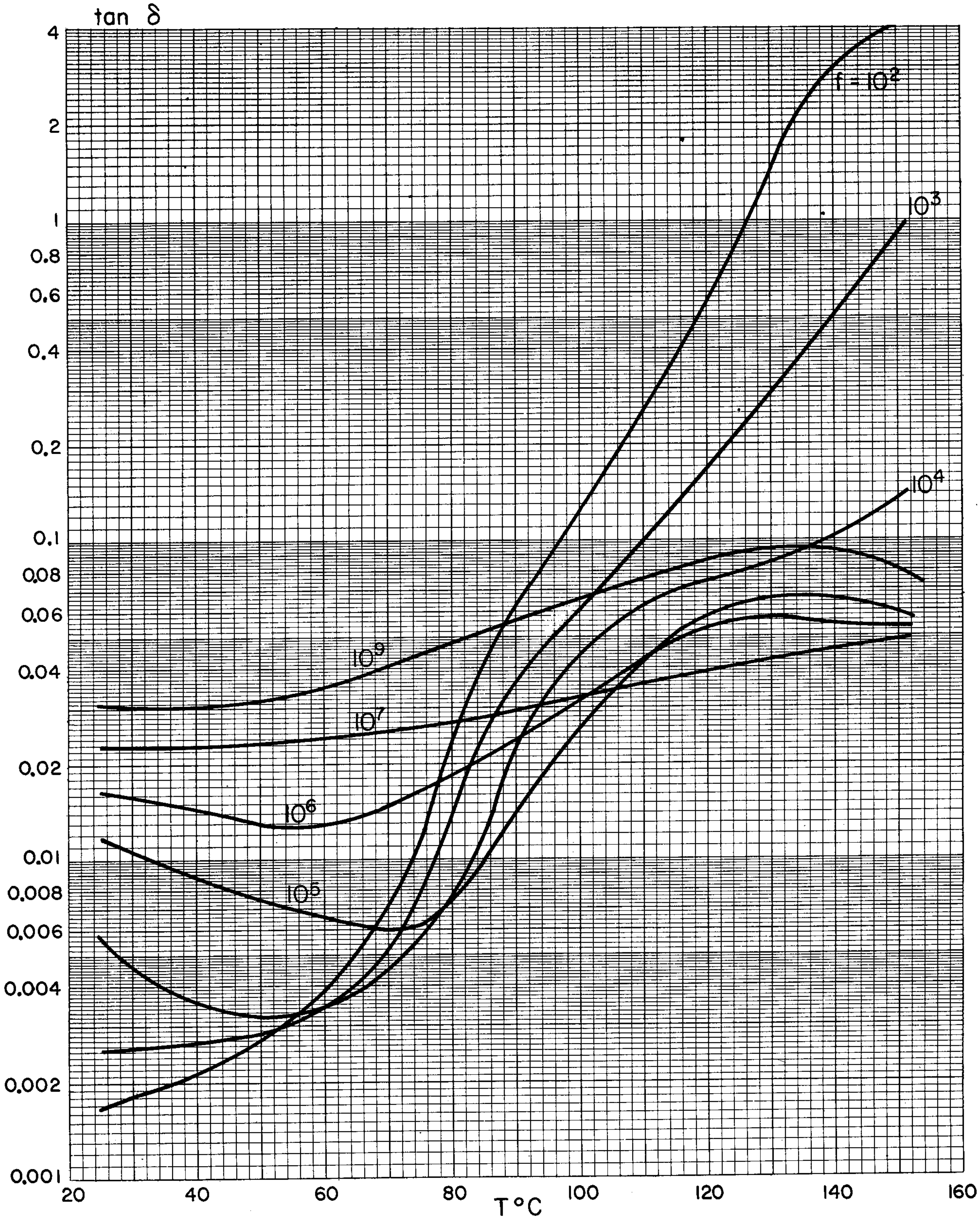
"Epon" 828 with "Piperidine" curing agent

Shell Chemical



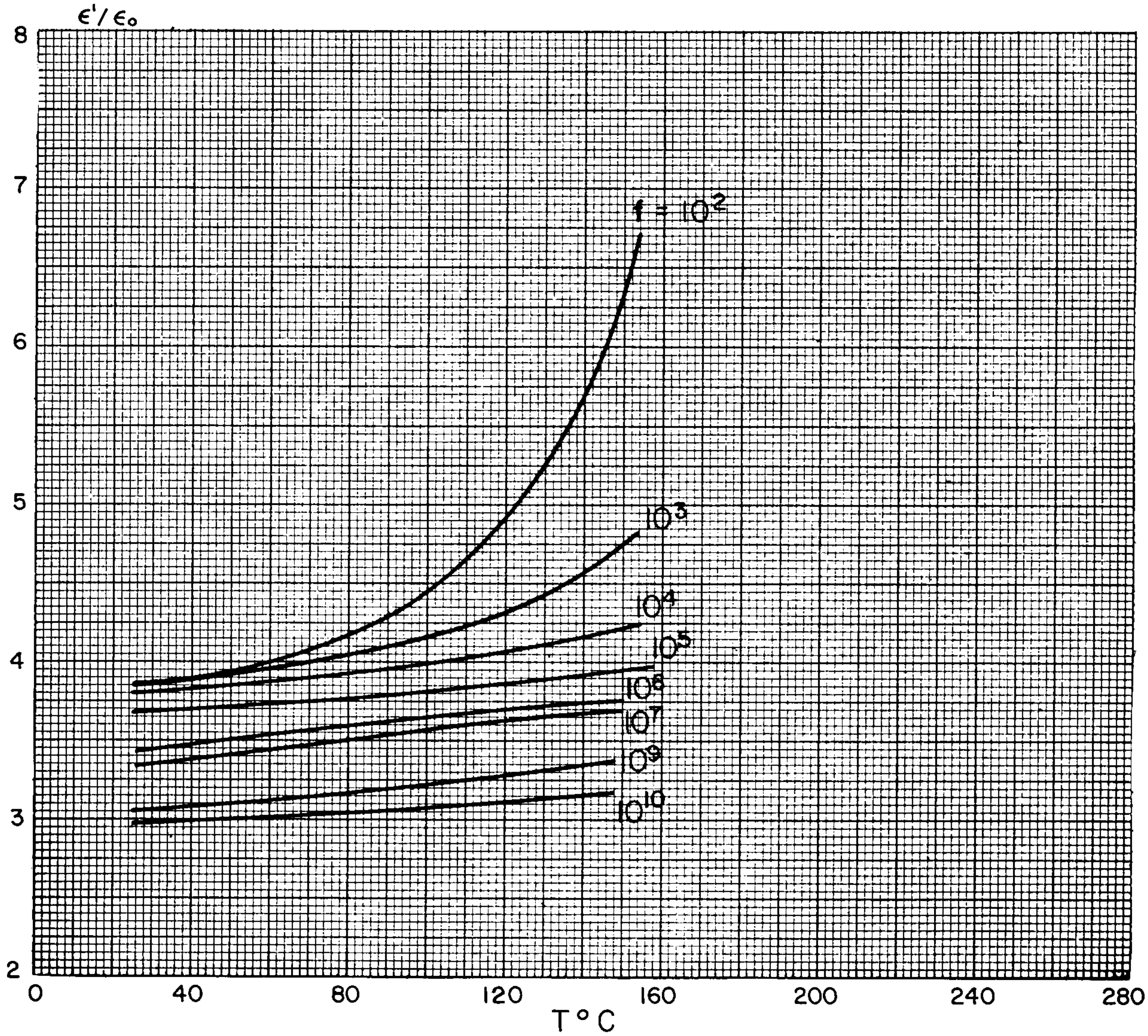
"Epon" 828 with "Piperidine" curing agent

Shell Chemical



III B 11. Epoxy Resins

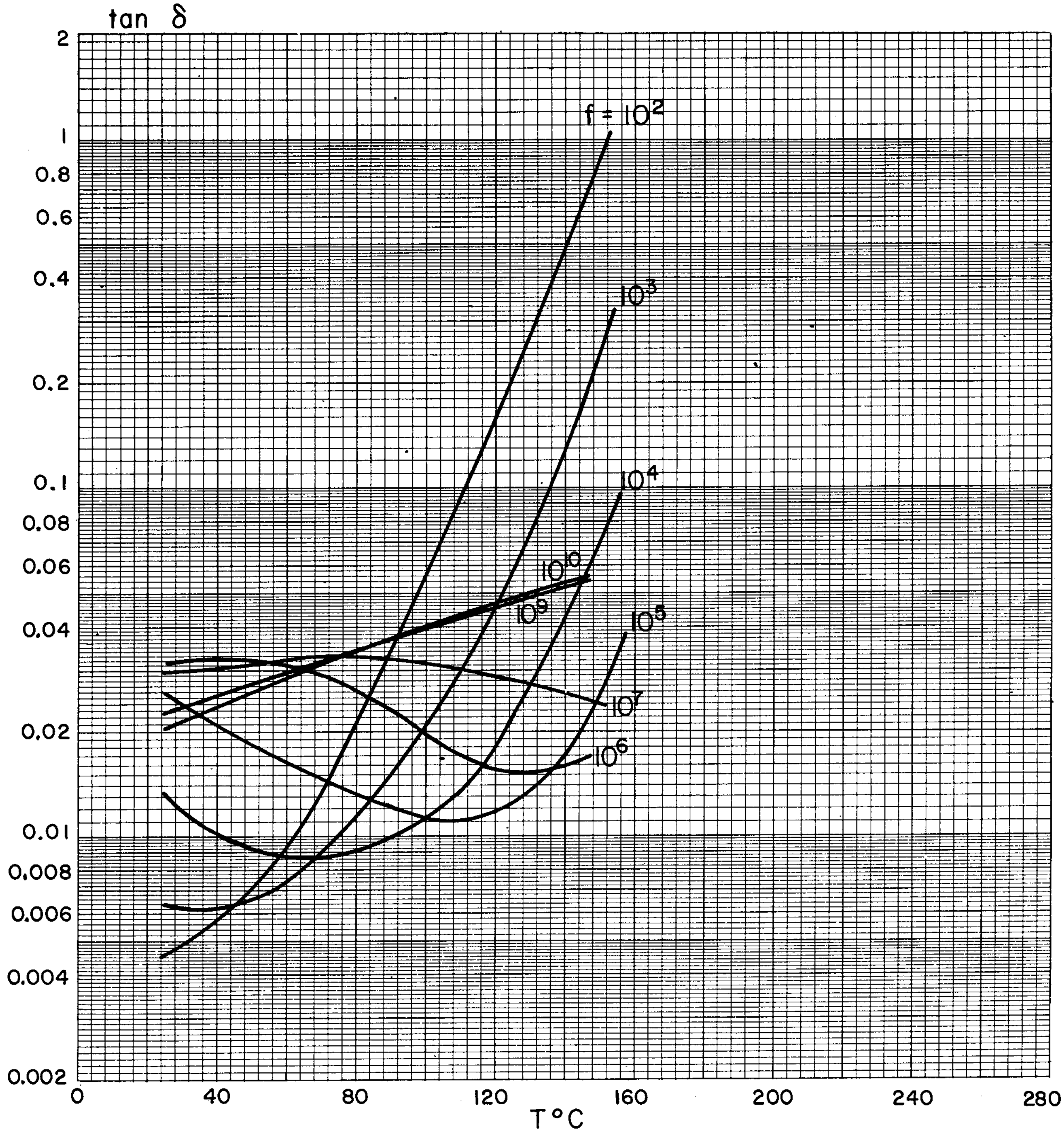
"Epon" 828 with curing agent BF_3-400 Shell Chemical



III B 11. Epoxy Resins

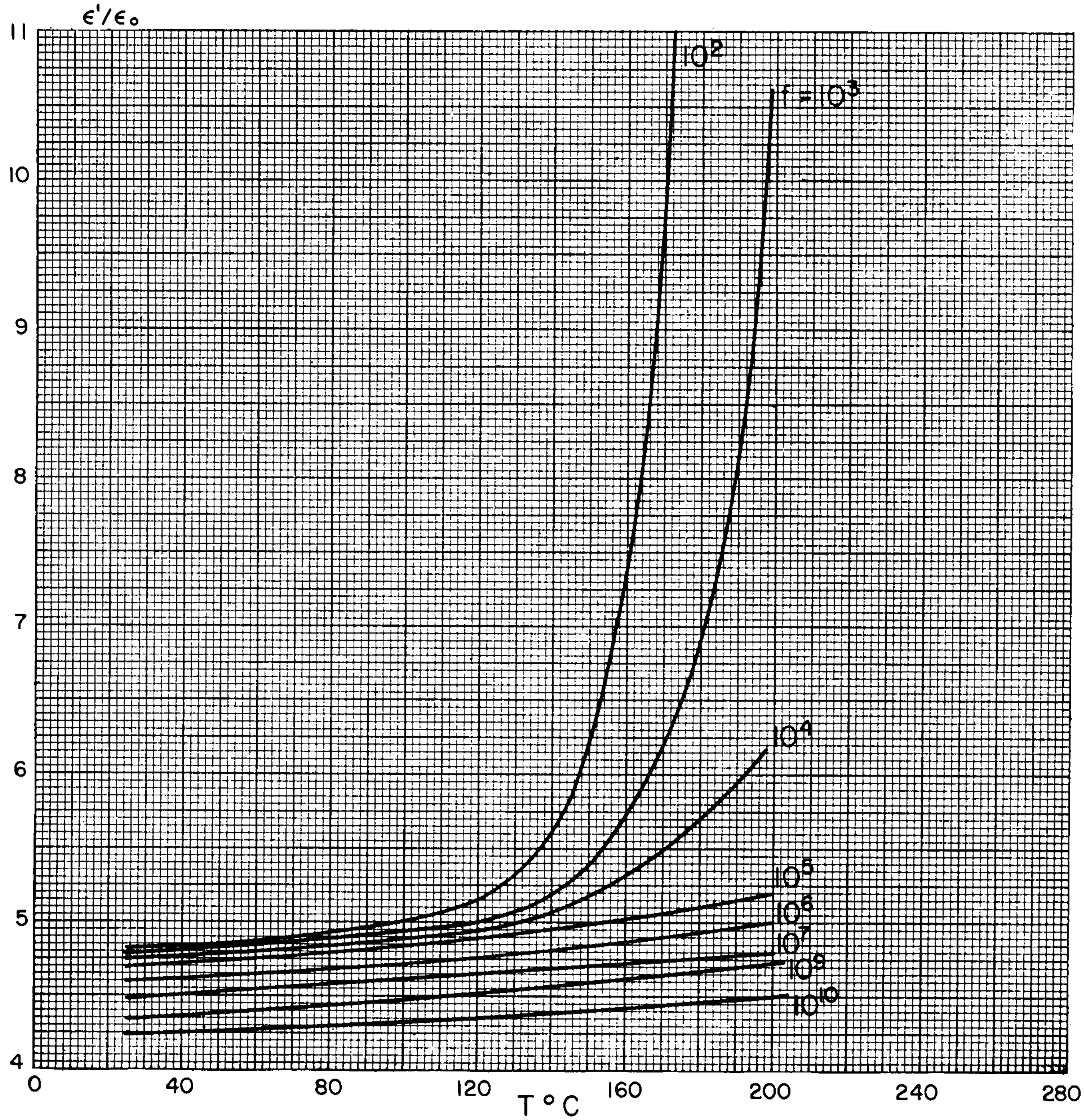
"Epon" 828 with curing agent BF_3-400

Shell Chemical



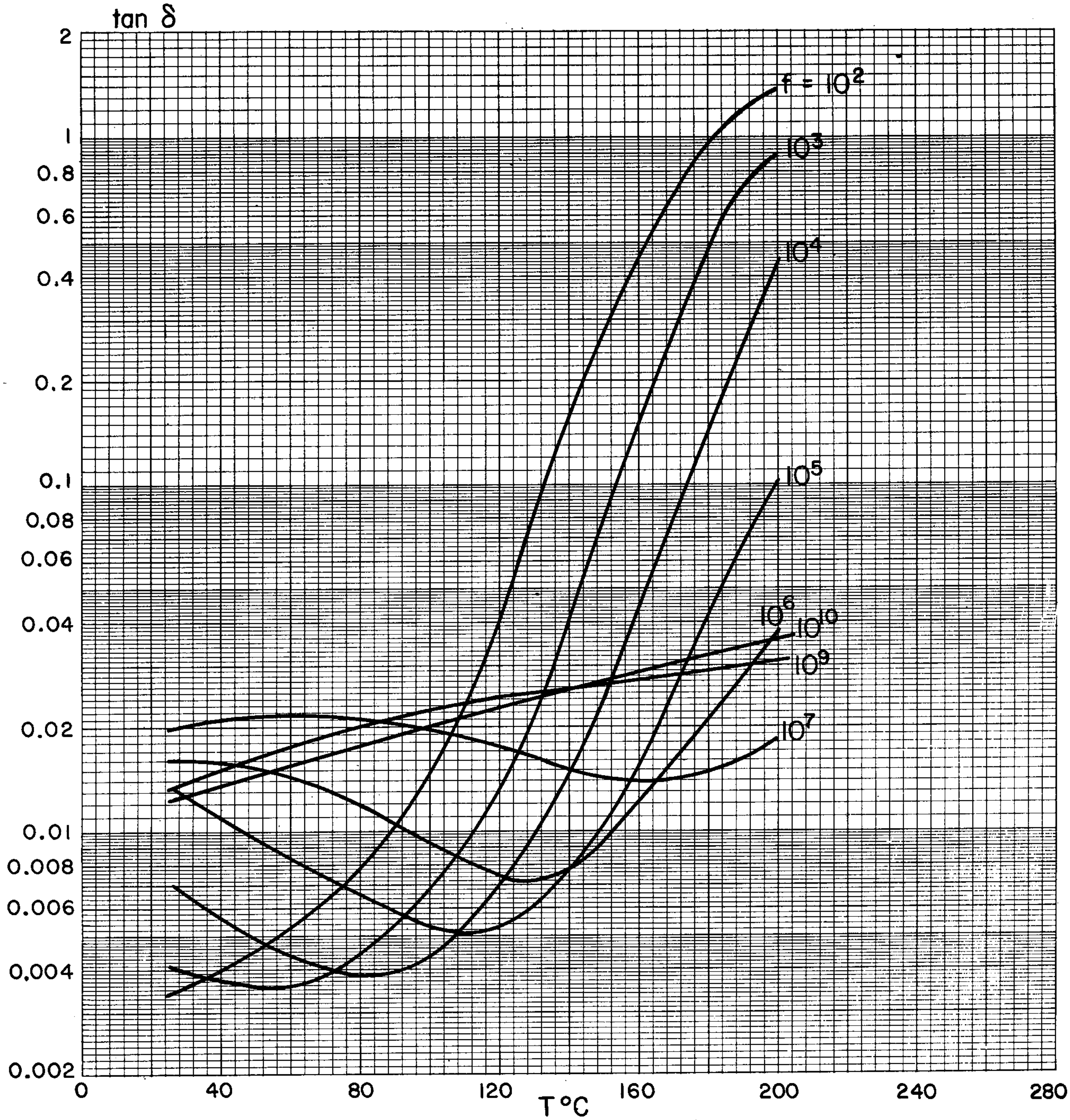
"Epon" 828 "fiberglas" laminate
(curing agent BF_3-400)

Shell Chemical



"Epon" 828 "fiberglas" laminate (curing agent BF_3-400)

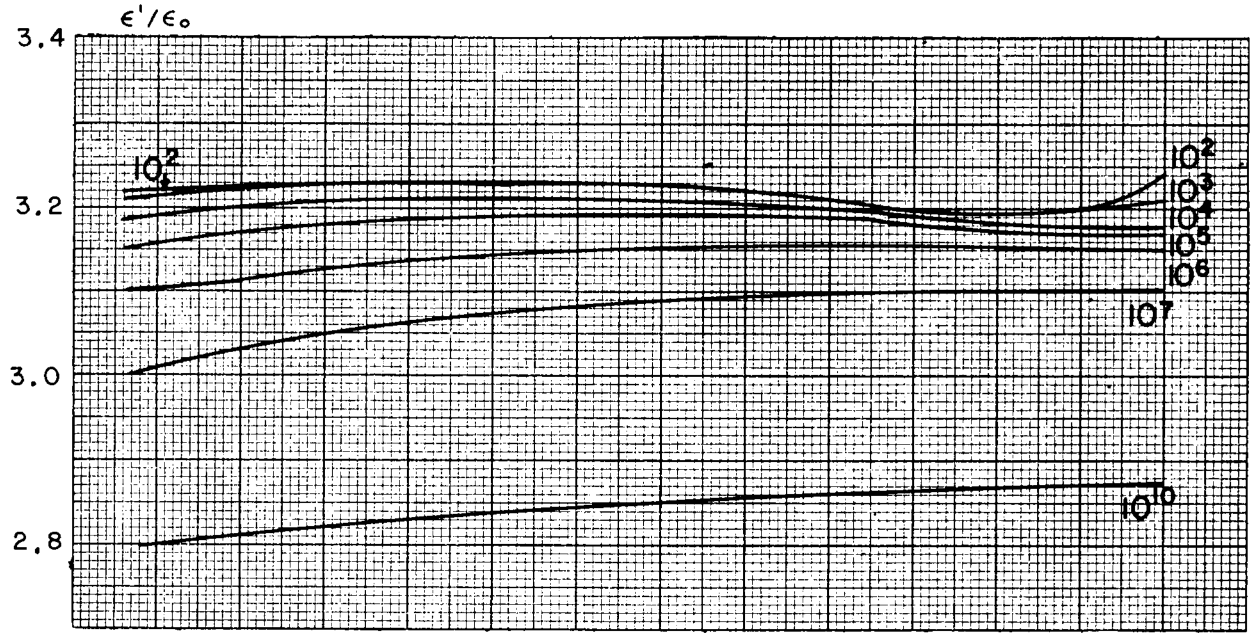
Shell Chemical

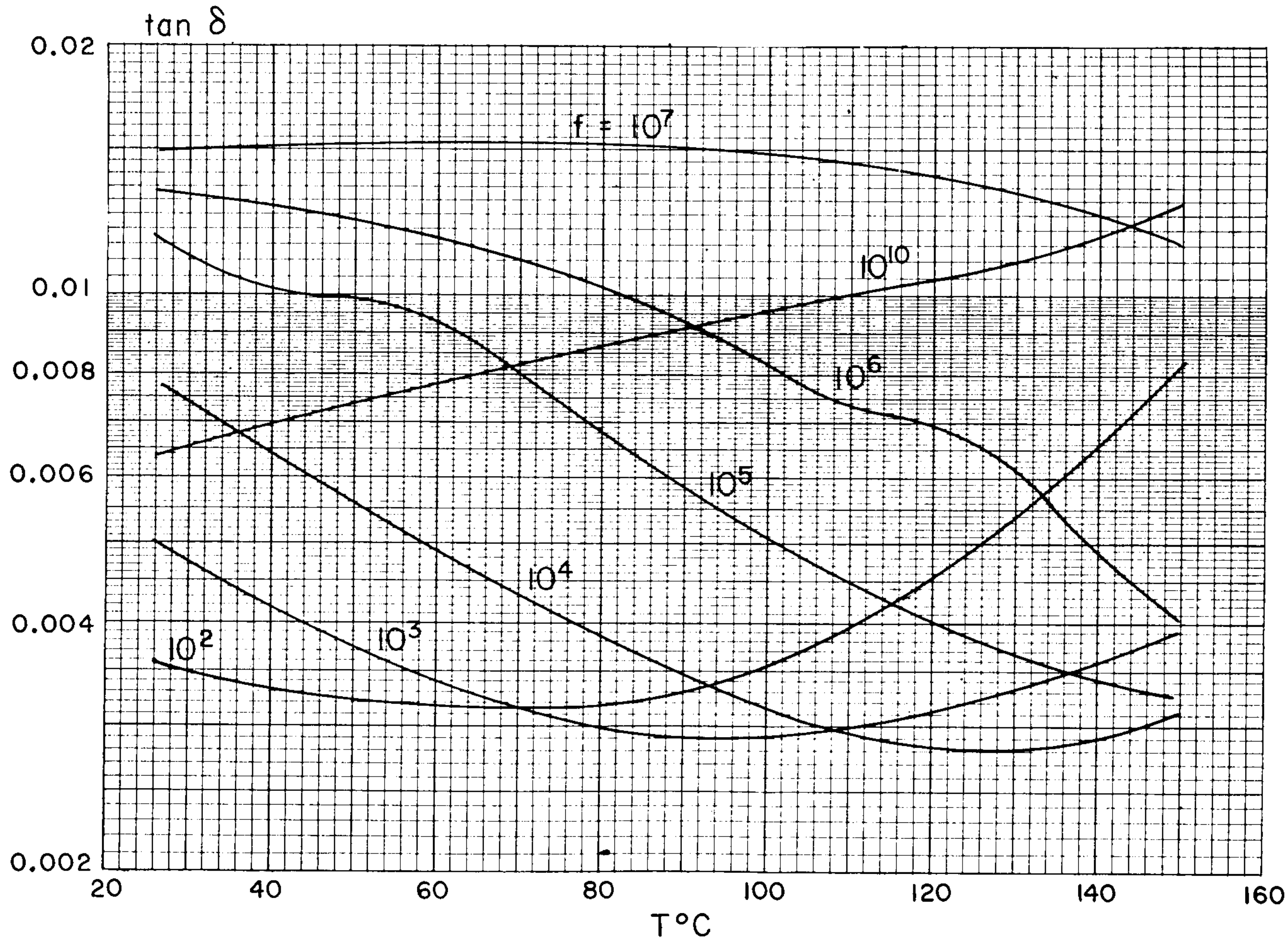


III B 11. Epoxy Resins

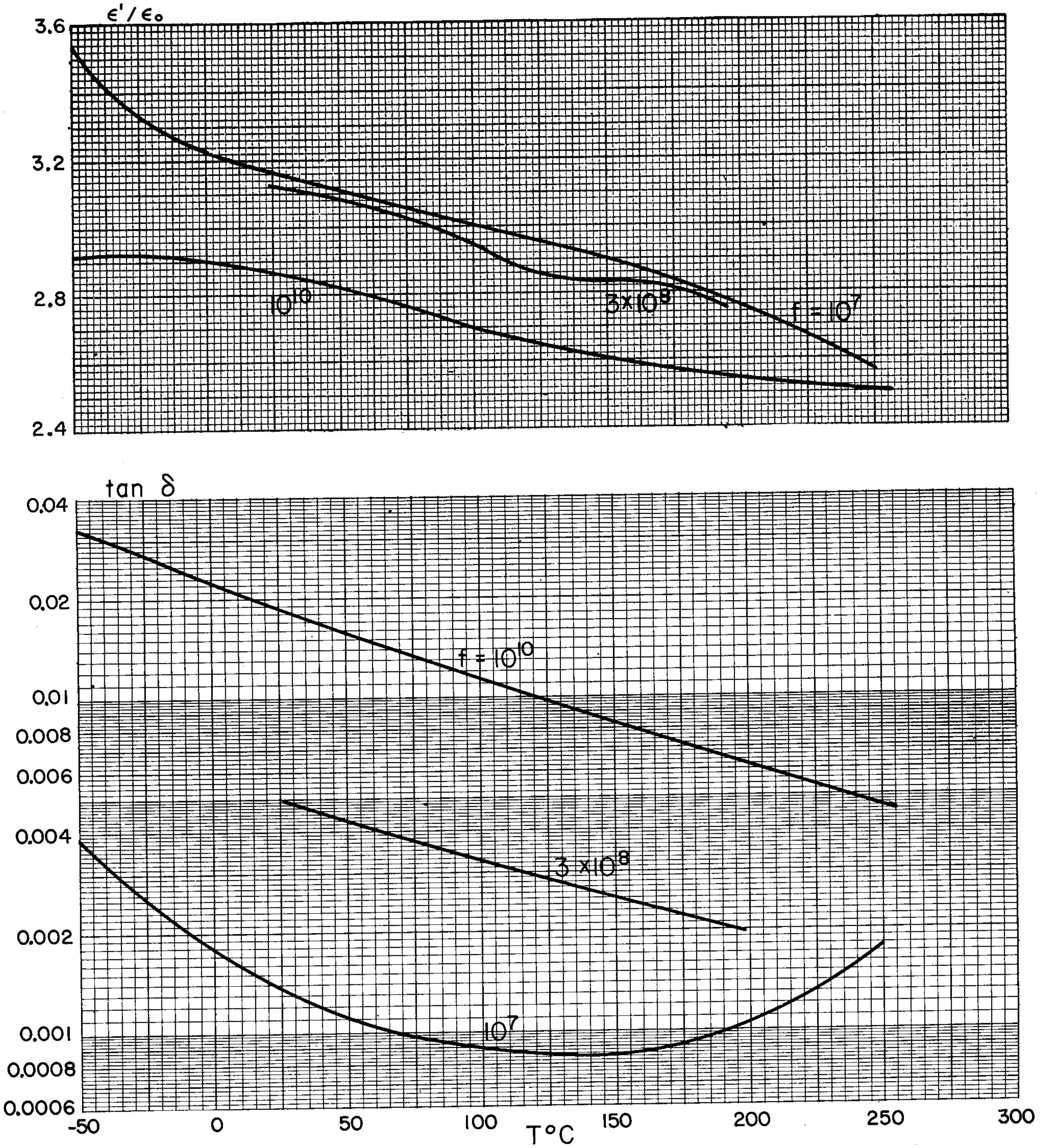
"Hysol" 6000HD

Houghton



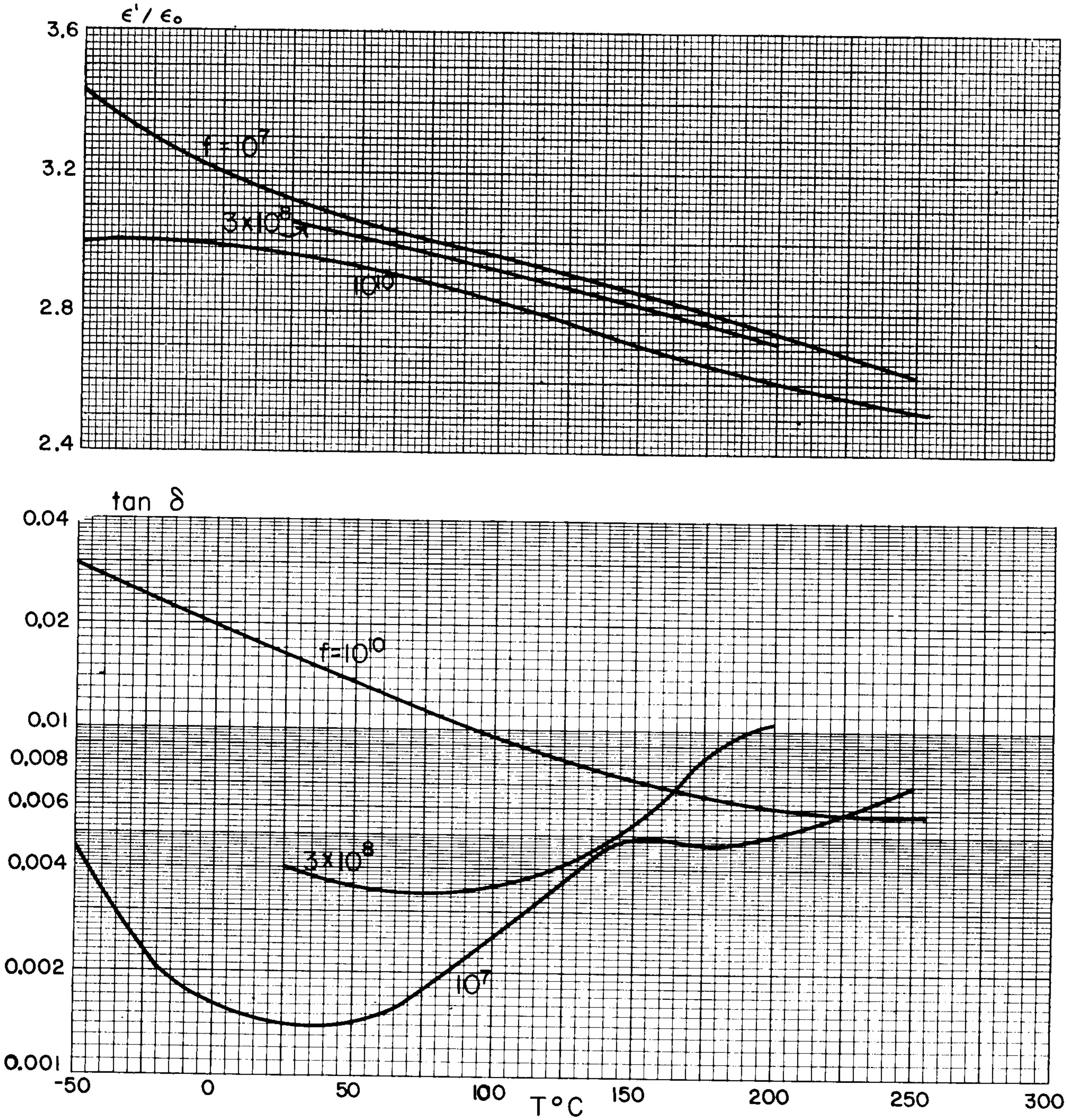


Silicone Rubber SE 450 General Electric, Waterford, N.Y.



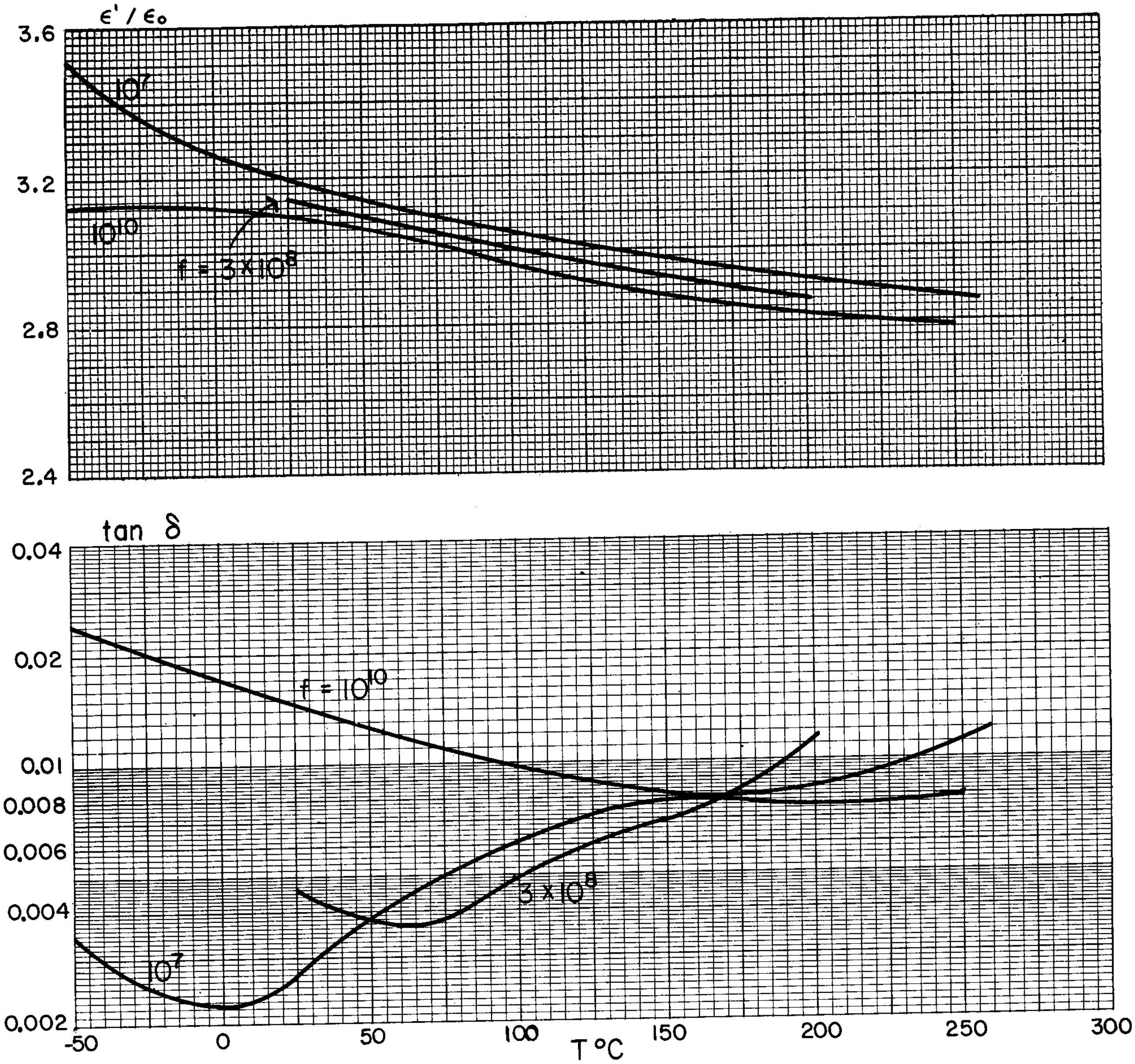
Silicone Rubber SE 460

General Electric, Waterford, N.Y.



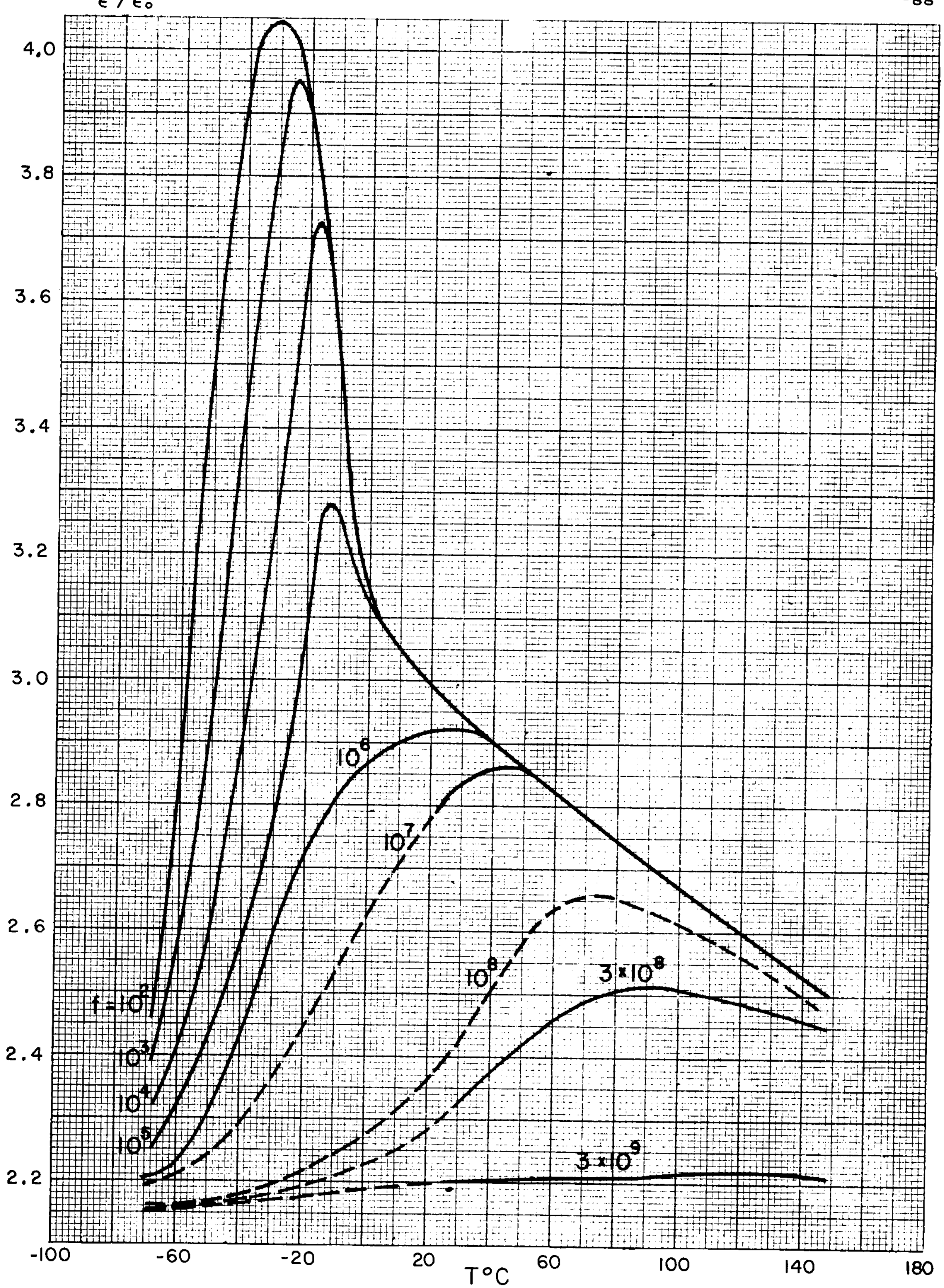
III C. Elastomers

Silicone Rubber SE 972 General Electric, Waterford, N.Y.

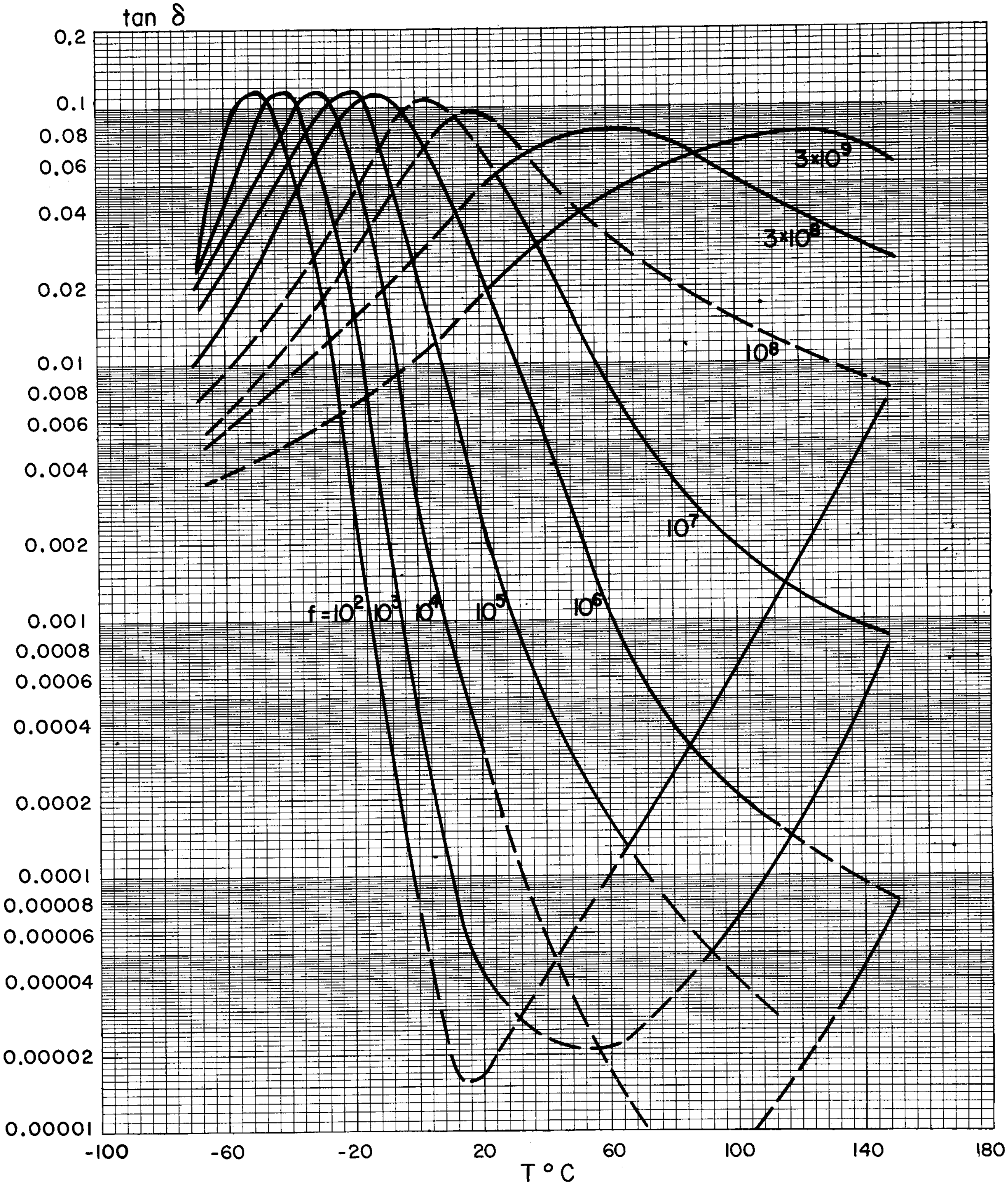


"Kel-F" Polymer Oil No. 10

M. W. Kellogg



"Kel-F" Polymer Oil No. 10 M. W. Kellogg



IV. Ferromagnetic Dielectrics

Complete evaluation of a magnetic material for both scientific study and engineering design requires measurement of κ^* and κ^*_m vs. frequency, temperature, a-c field strength, and d-c bias. Phenomena of interest range from the very slow changes in magnetization with time at low temperatures to the instantaneous permeability at high microwave power.

In this section we have limited our data to κ^* and κ^*_m vs. frequency at low a-c field strengths and fixed temperatures and to the quasi-static hysteresis loops at room temperature. At frequencies up to 10 Mc we have also plotted κ''_m/κ'_m, a figure of merit for core materials. In the literature this is designated as $1/\mu'Q$ and called loss factor.

For many of the laboratory materials and some of the commercial materials other measurements have been made such as:

D-c conductivity vs. temperature,

κ^*, κ^*_m vs. temperature at fixed frequencies, low fields,

κ^*, κ^*_m vs. field strength at fixed frequencies and temperatures.

Some of this information is included in Tech. Rep. 97, a revised version of which will be published in Revs. Mod. Phys., July, 1957, and in a forthcoming technical report by D. J. Epstein. Other data are available from the measurements group file.

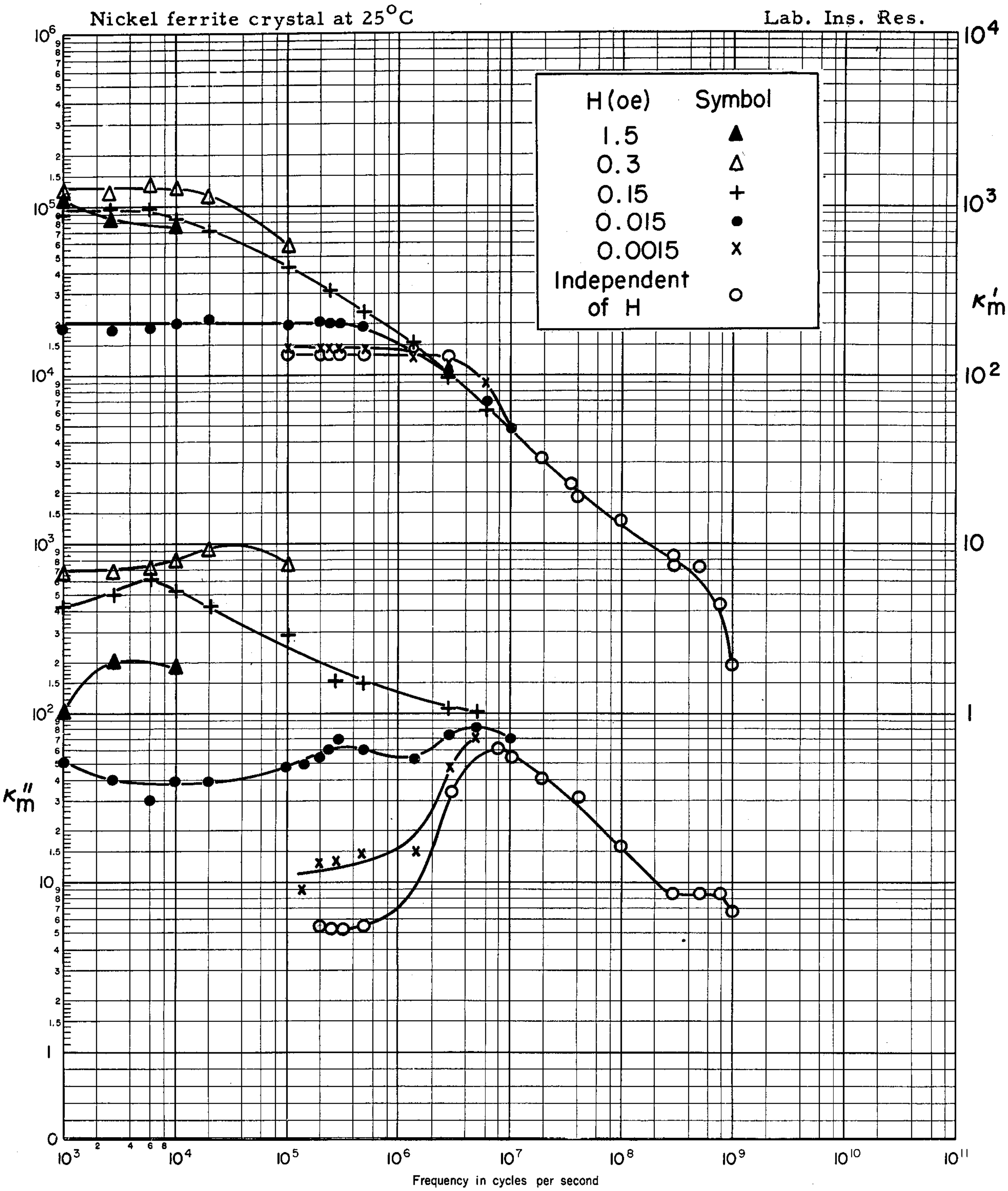
Details of the preparation of ferrites have been given in Tech. Rep. 78 by G. Economos.

Unless otherwise noted, measurements were taken at $26^{\circ}C \pm 1$. σ is given in mho/m.

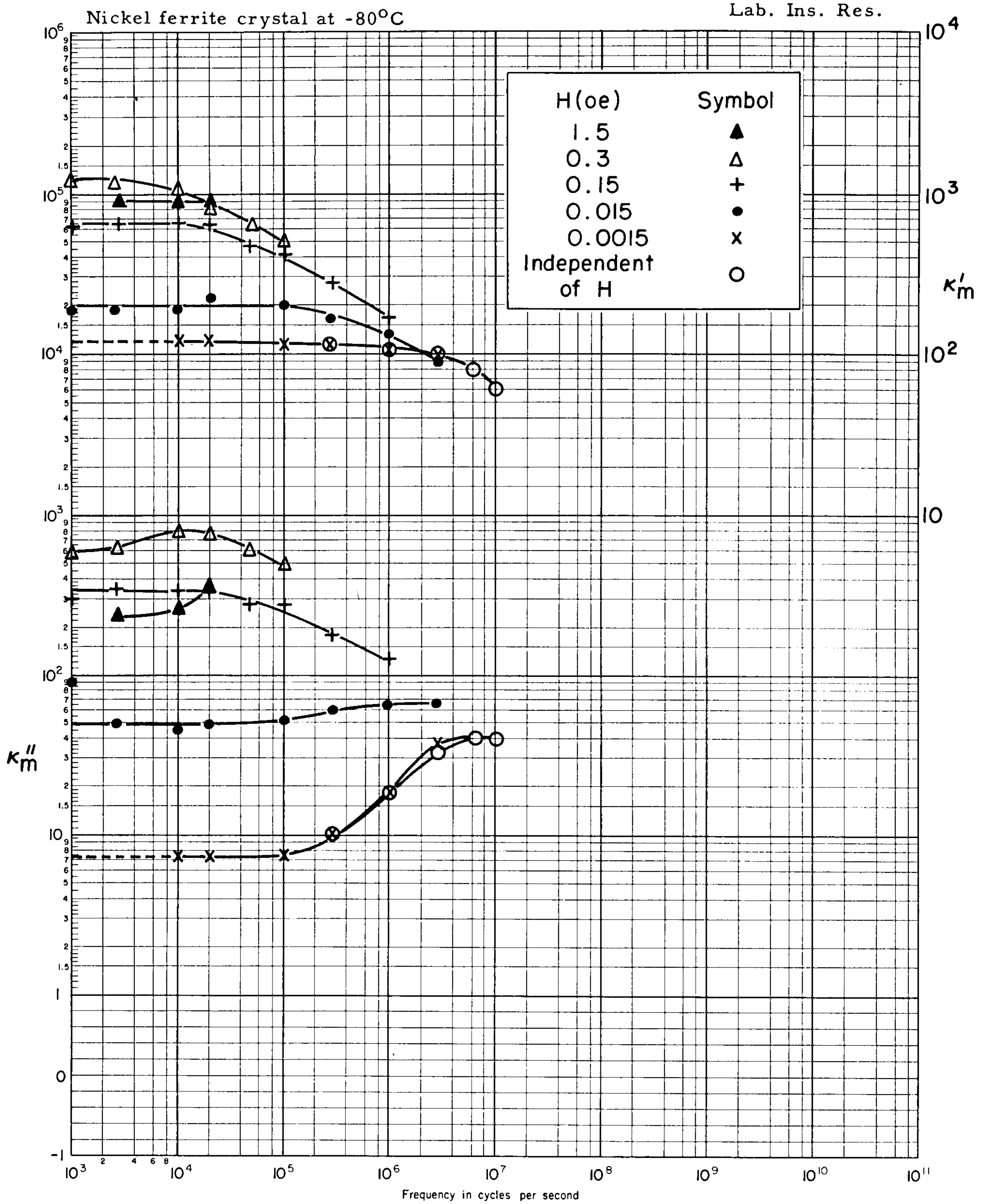
Low-frequency dielectric measurements marked ⊗ were four-terminal measurements made to eliminate electrode effects.

IV A. Low Field-Strength Data at Fixed Temperatures as a Function of Frequency

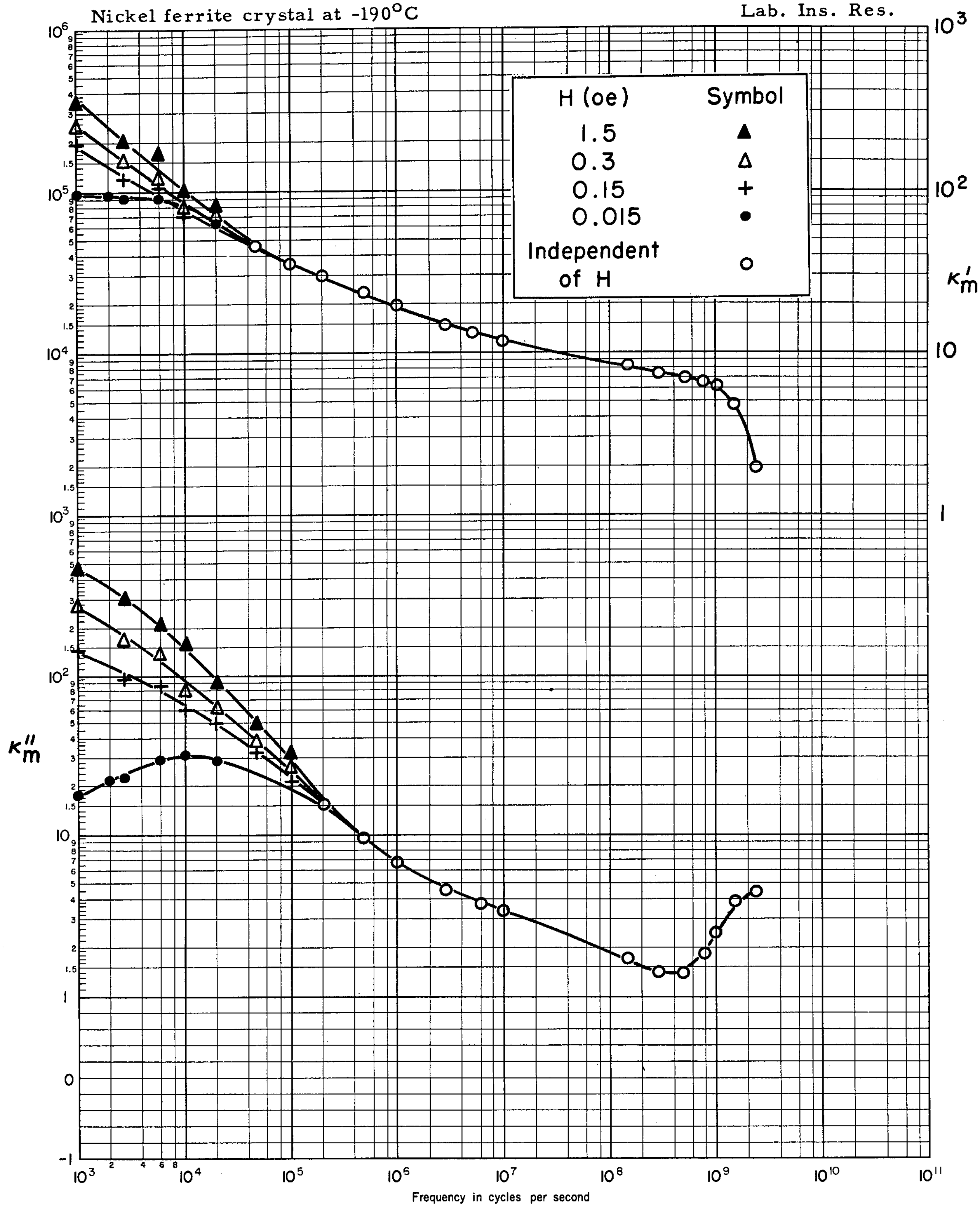
1. Nickel Ferrite, Single Crystal



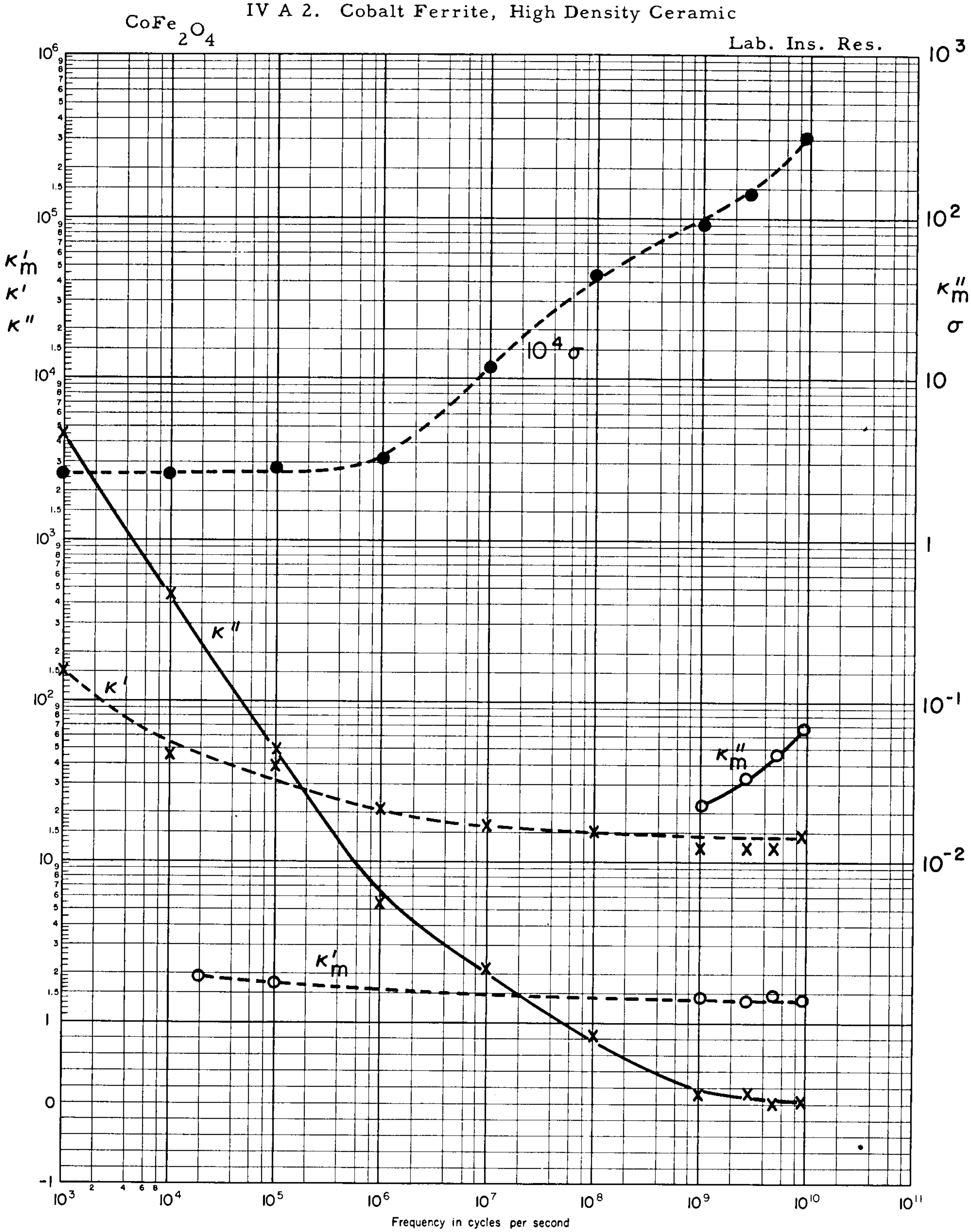
IV A 1. Nickel Ferrite, Single Crystal



IV A 1. Nickel Ferrite, Single Crystal

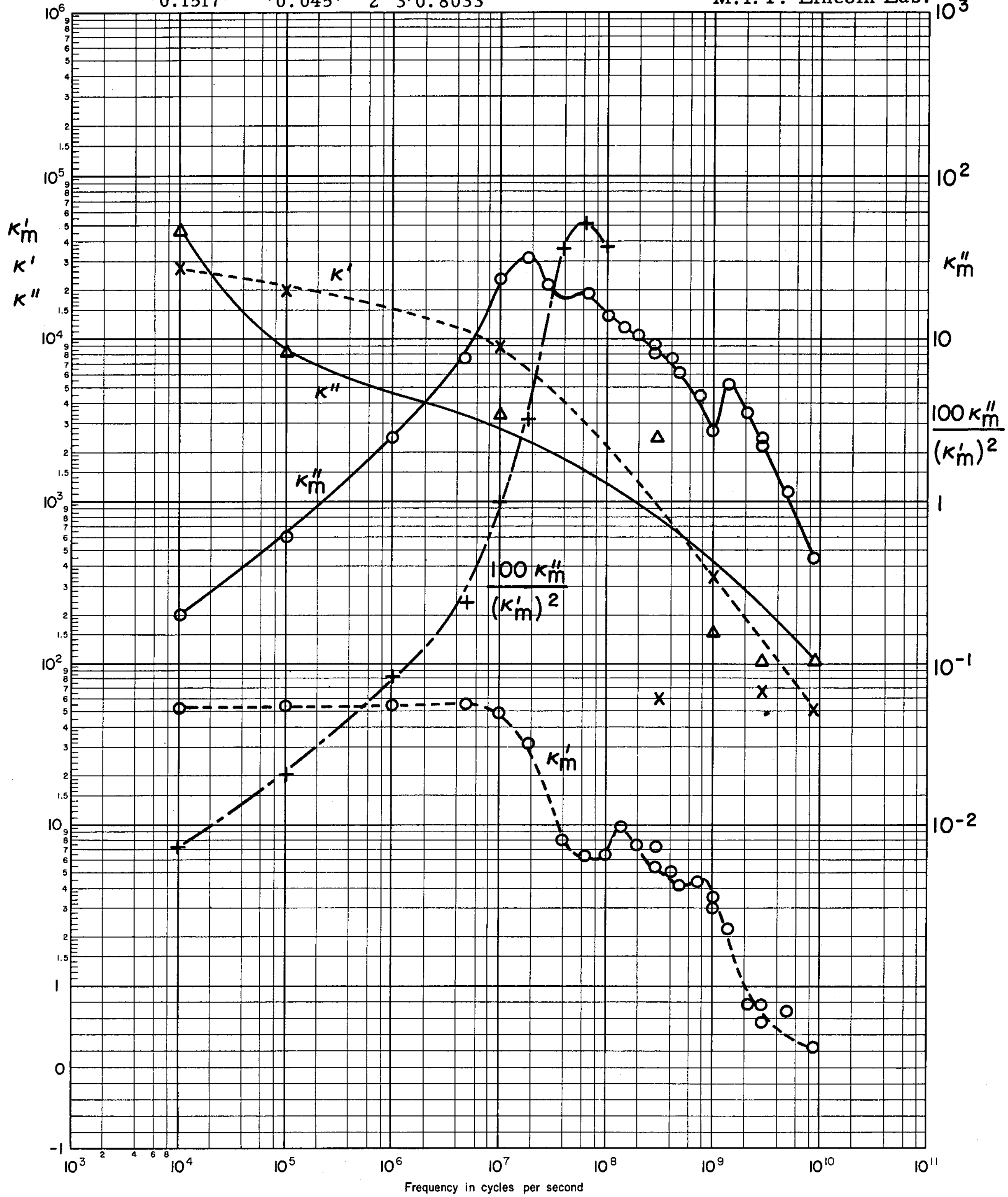


IV A 2. Cobalt Ferrite, High Density Ceramic

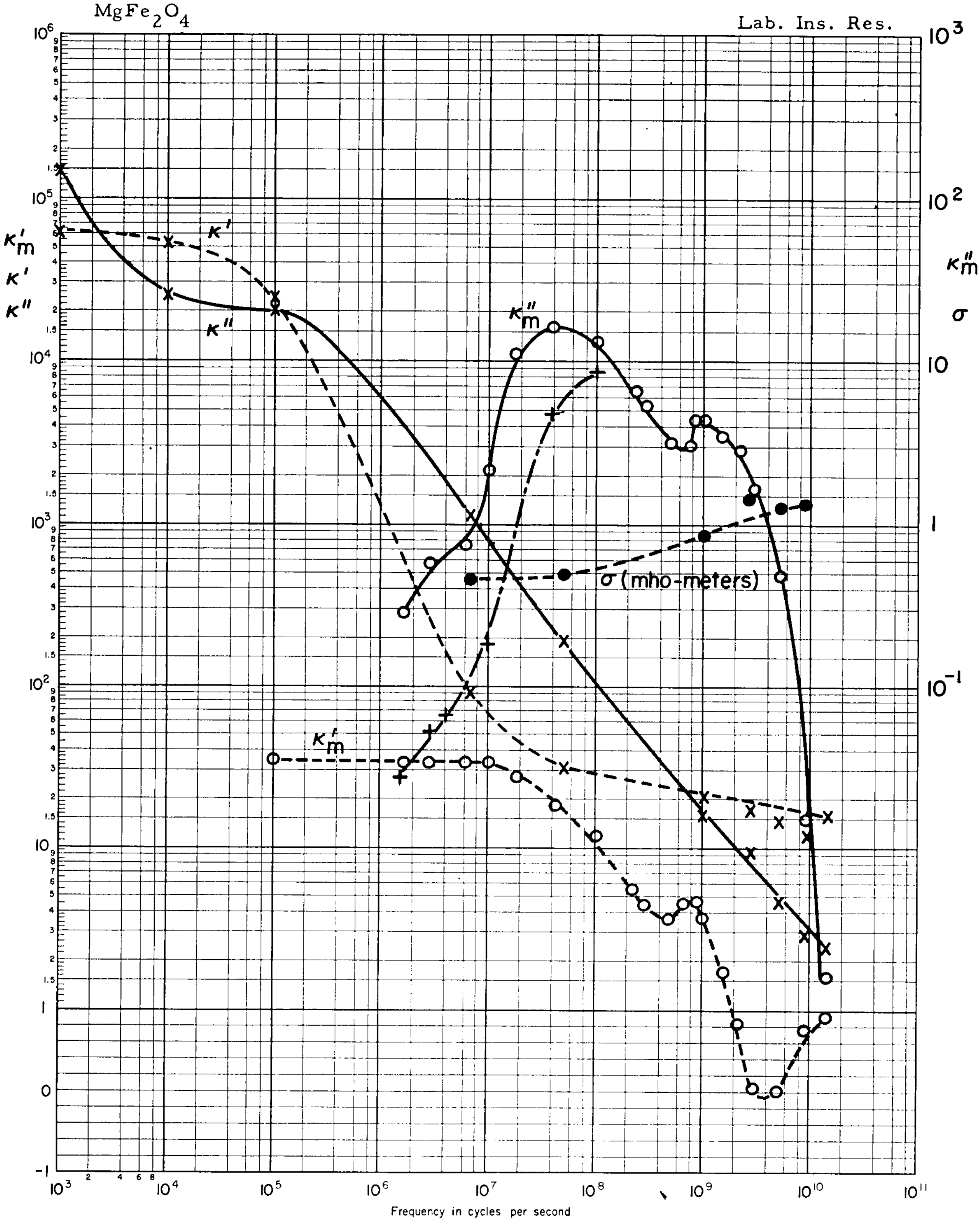


IV A 3. Lithium-Nickel Ferrite Ceramic

$(LiO)_{0.1517}(NiO)_{0.045}(Fe_2O_3)_{0.8033}$ M.I.T. Lincoln Lab.

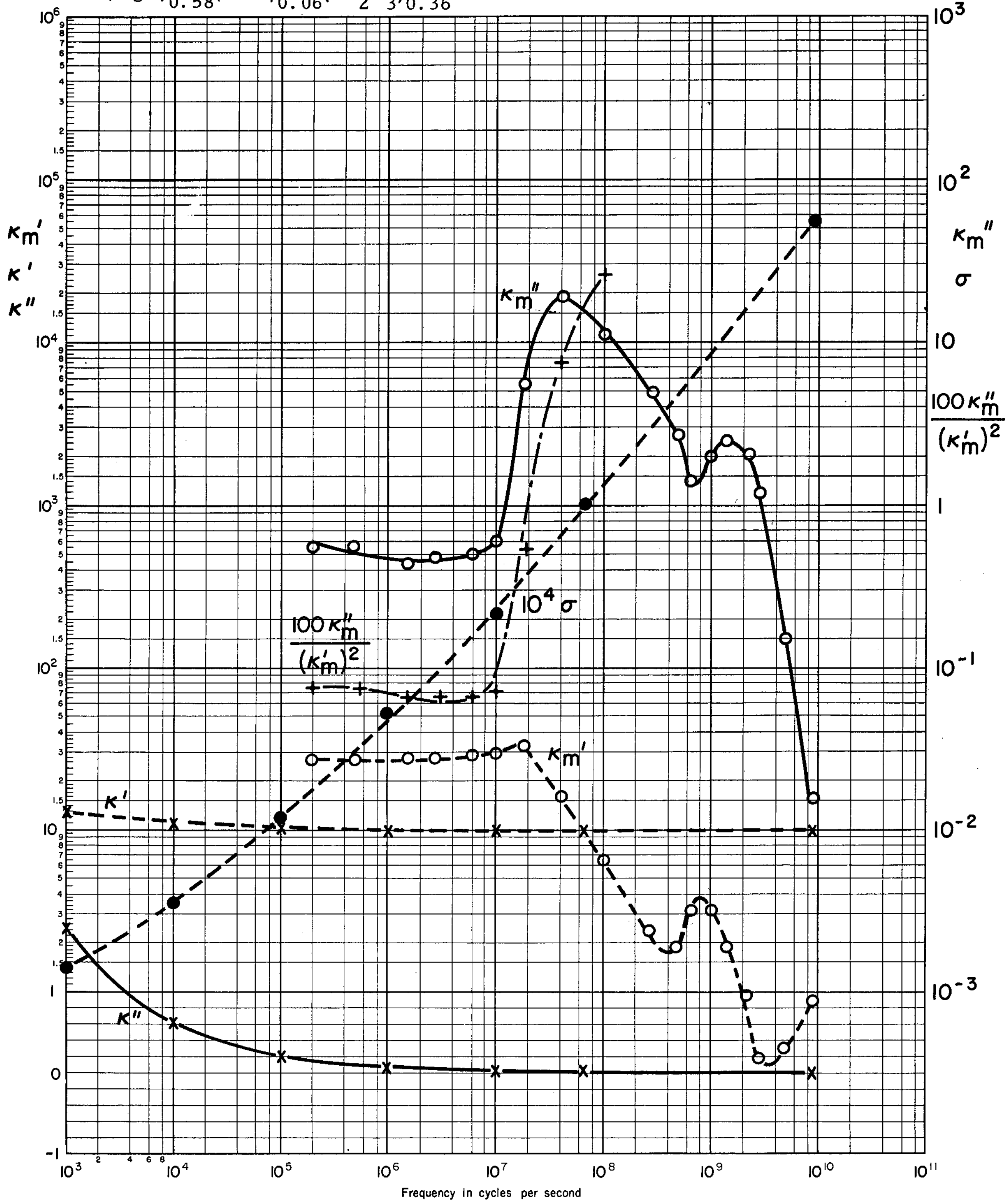


IV A 4. Magnesium Ferrite, High Density Ceramic



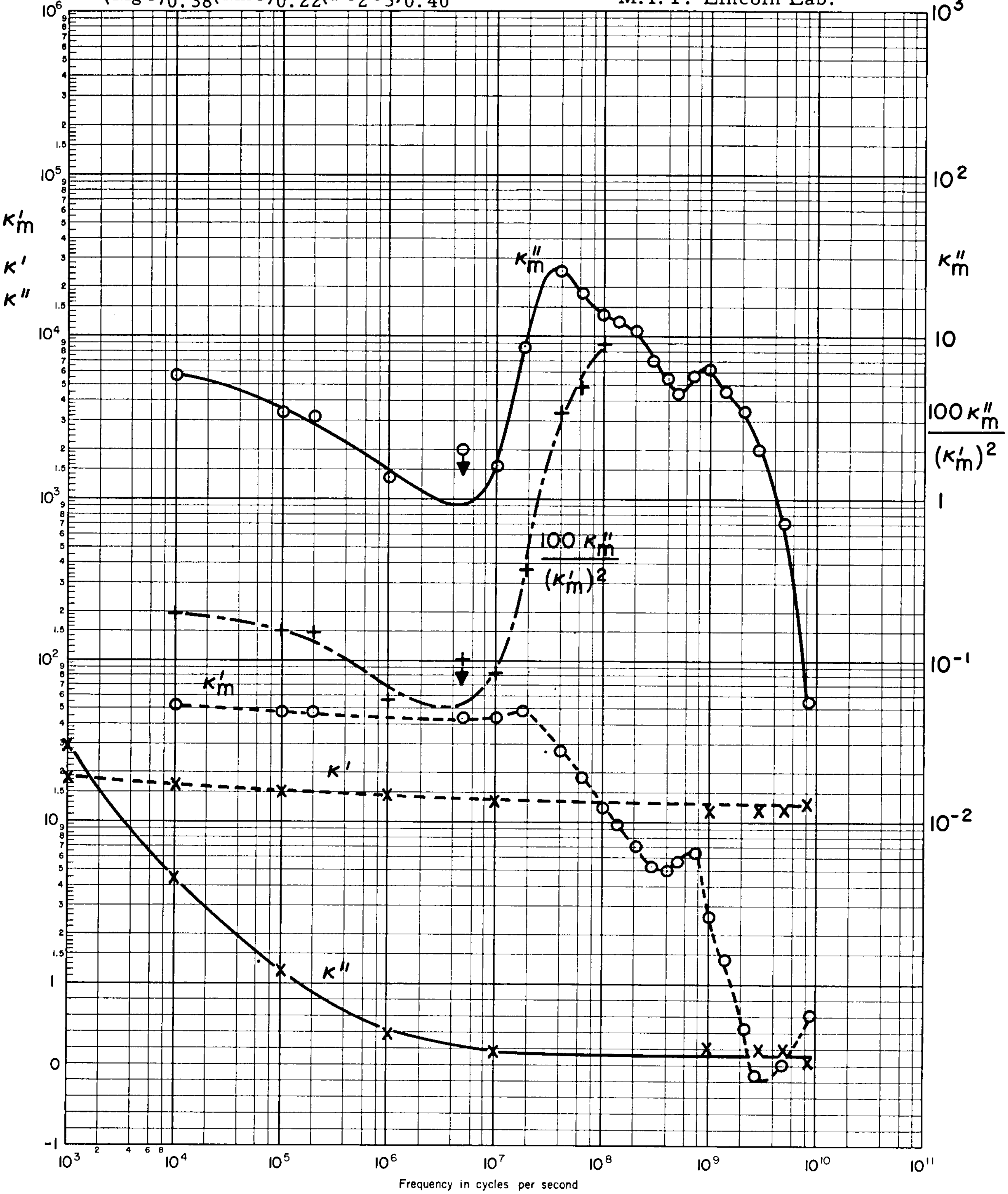
IV A 5. Magnesium Manganese Ferrite Ceramics

$(MgO)_{0.58}(MnO)_{0.06}(Fe_2O_3)_{0.36}$ Lab. Ins. Res.



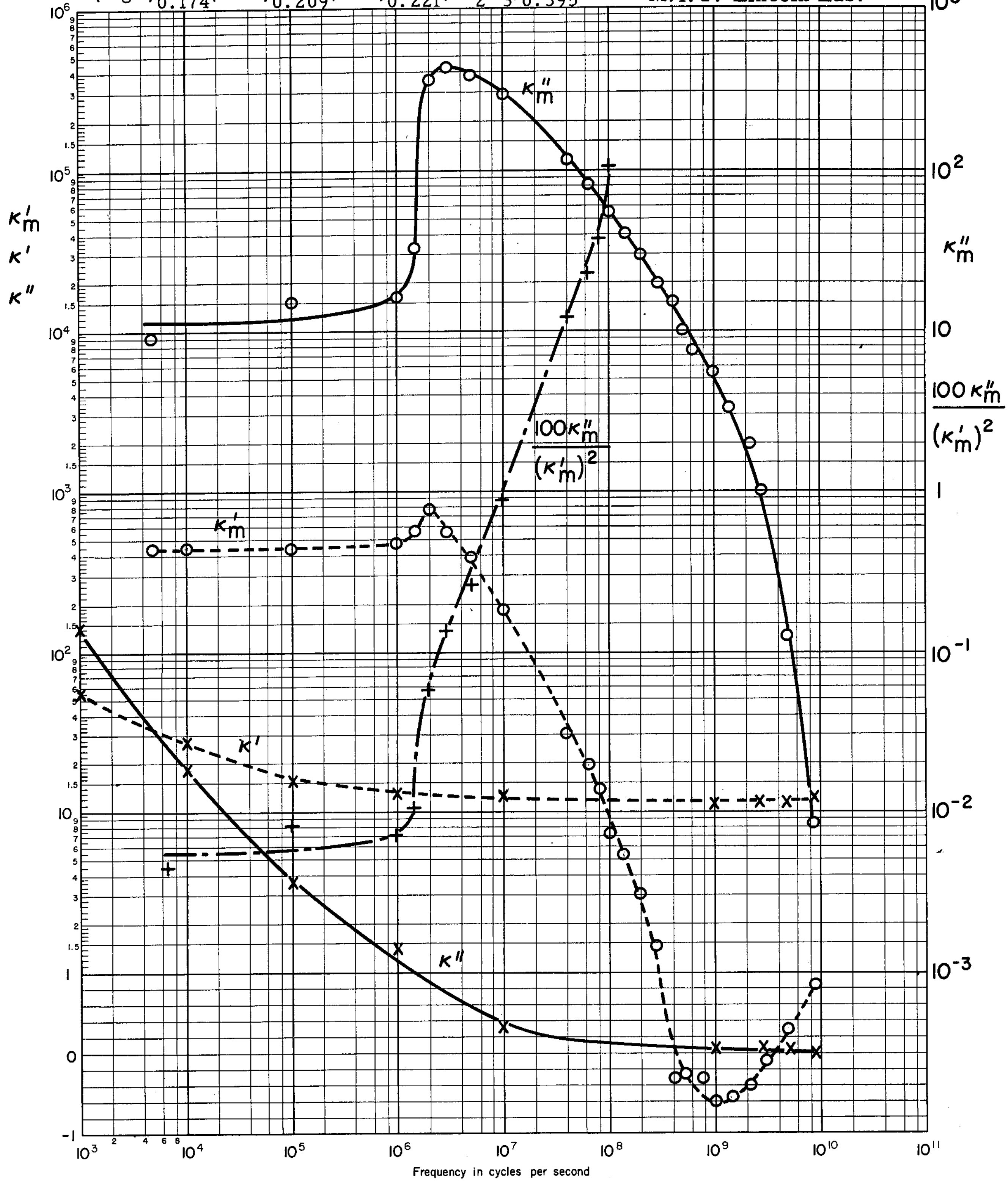
IV A 5. Magnesium-Manganese Ferrite Ceramics

$(MgO)_{0.38}(MnO)_{0.22}(Fe_2O_3)_{0.40}$ M.I.T. Lincoln Lab.

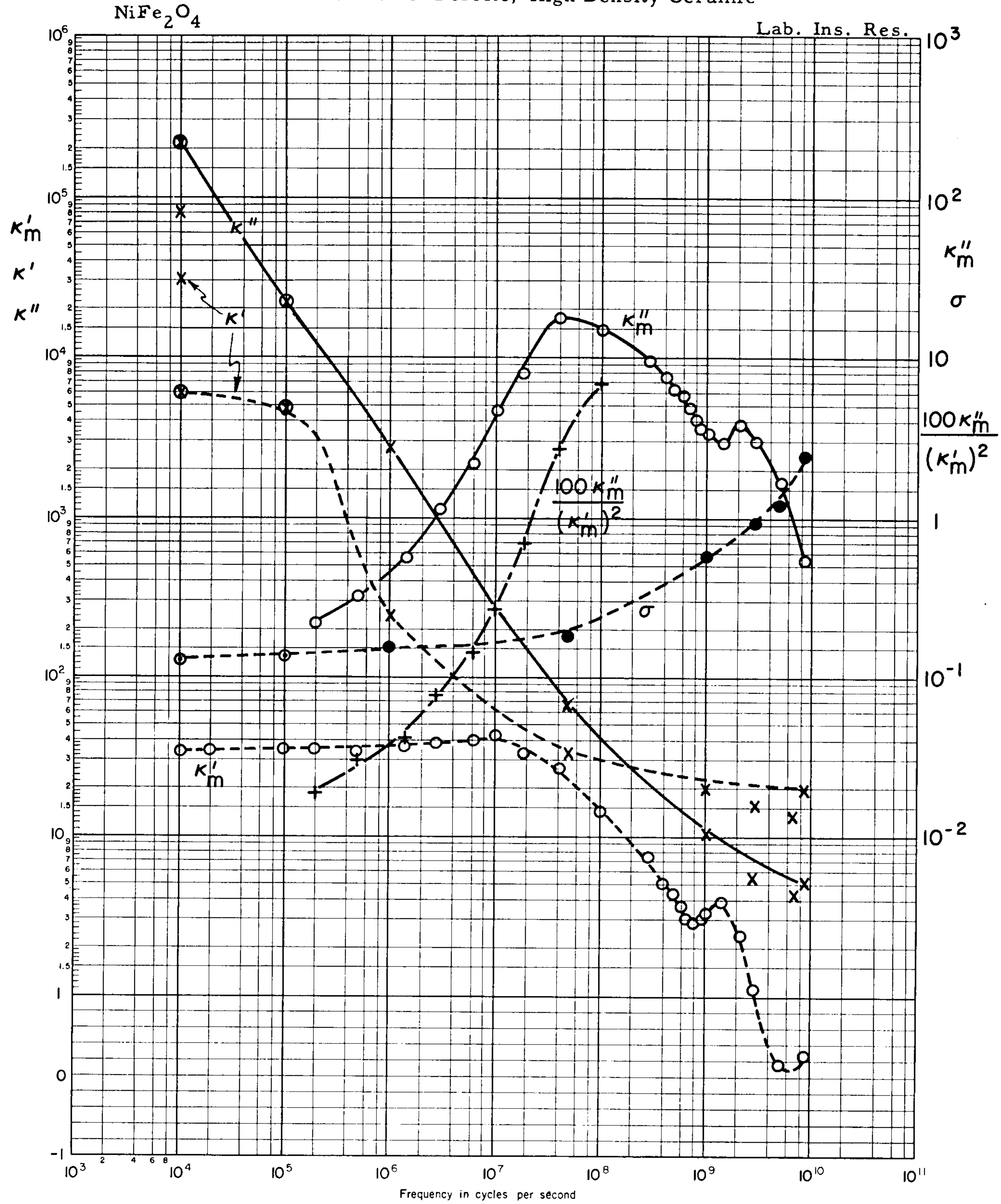


IV A 6. Magnesium-Manganese-Zinc Ferrite Ceramic

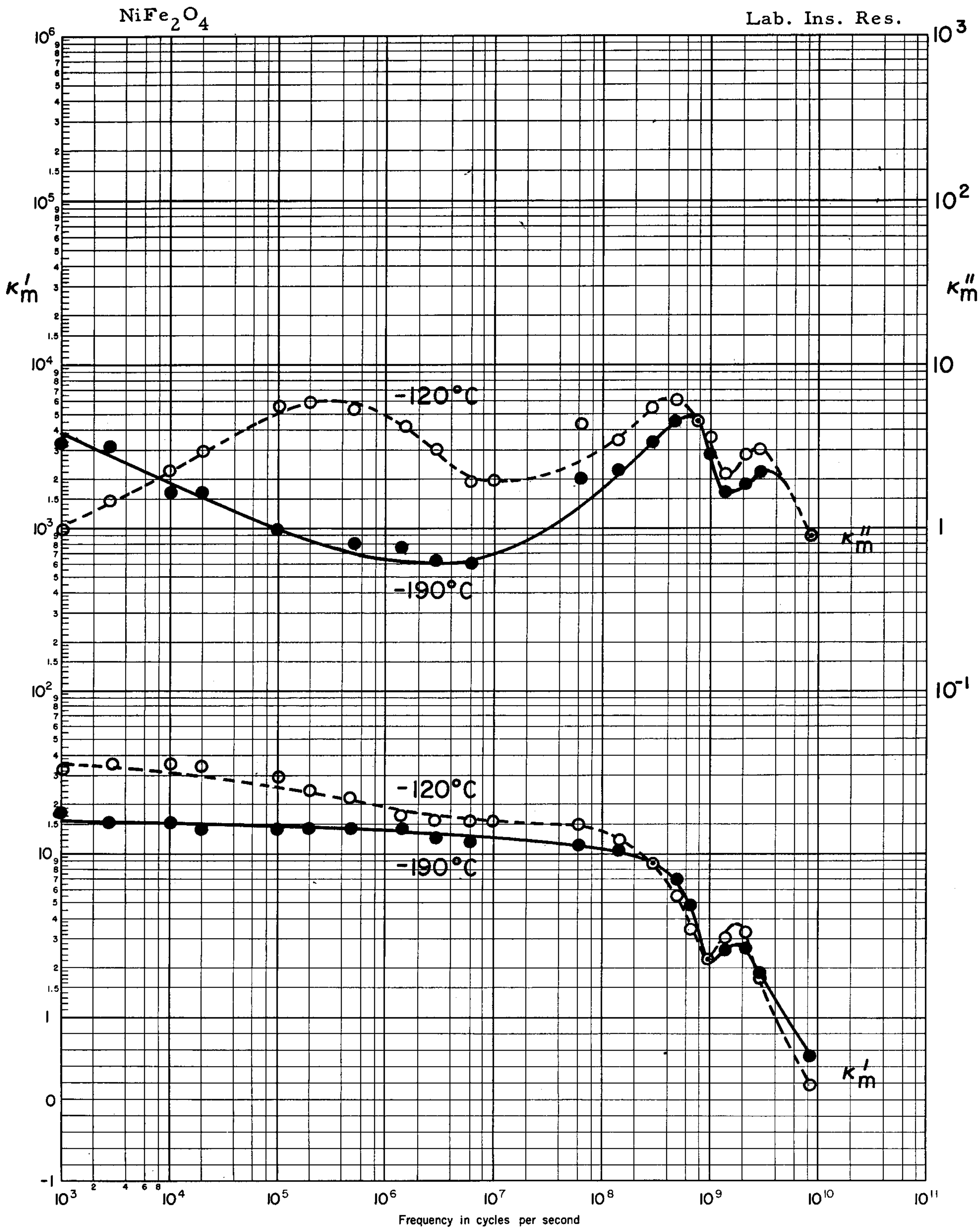
$(MgO)_{0.174}(MnO)_{0.209}(ZnO)_{0.221}(Fe_2O_3)_{0.395}$ M.I.T. Lincoln Lab.



IV A 7. Nickel Ferrite, High Density Ceramic

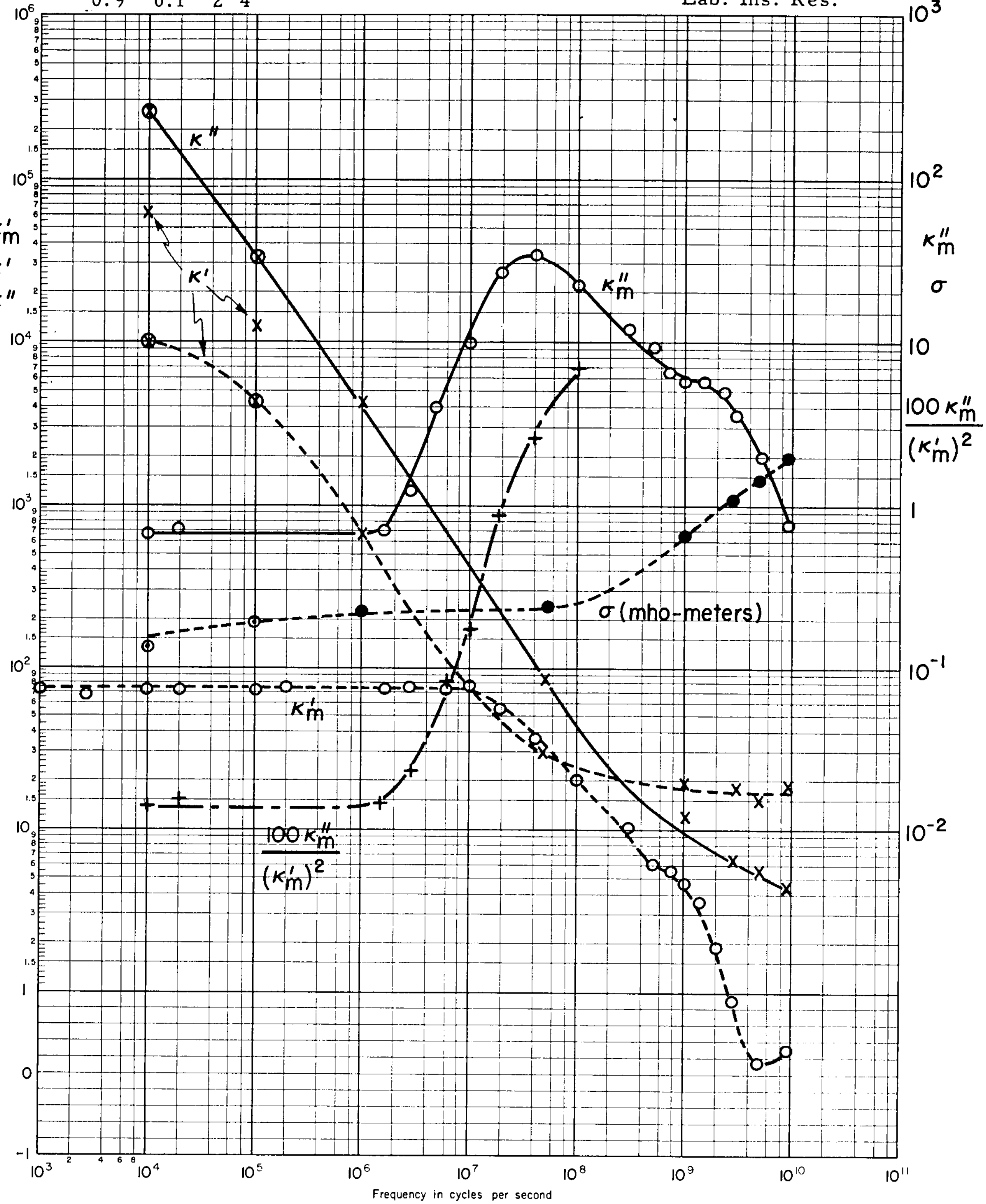


IV A 7. Nickel Ferrite, High Density Ceramic



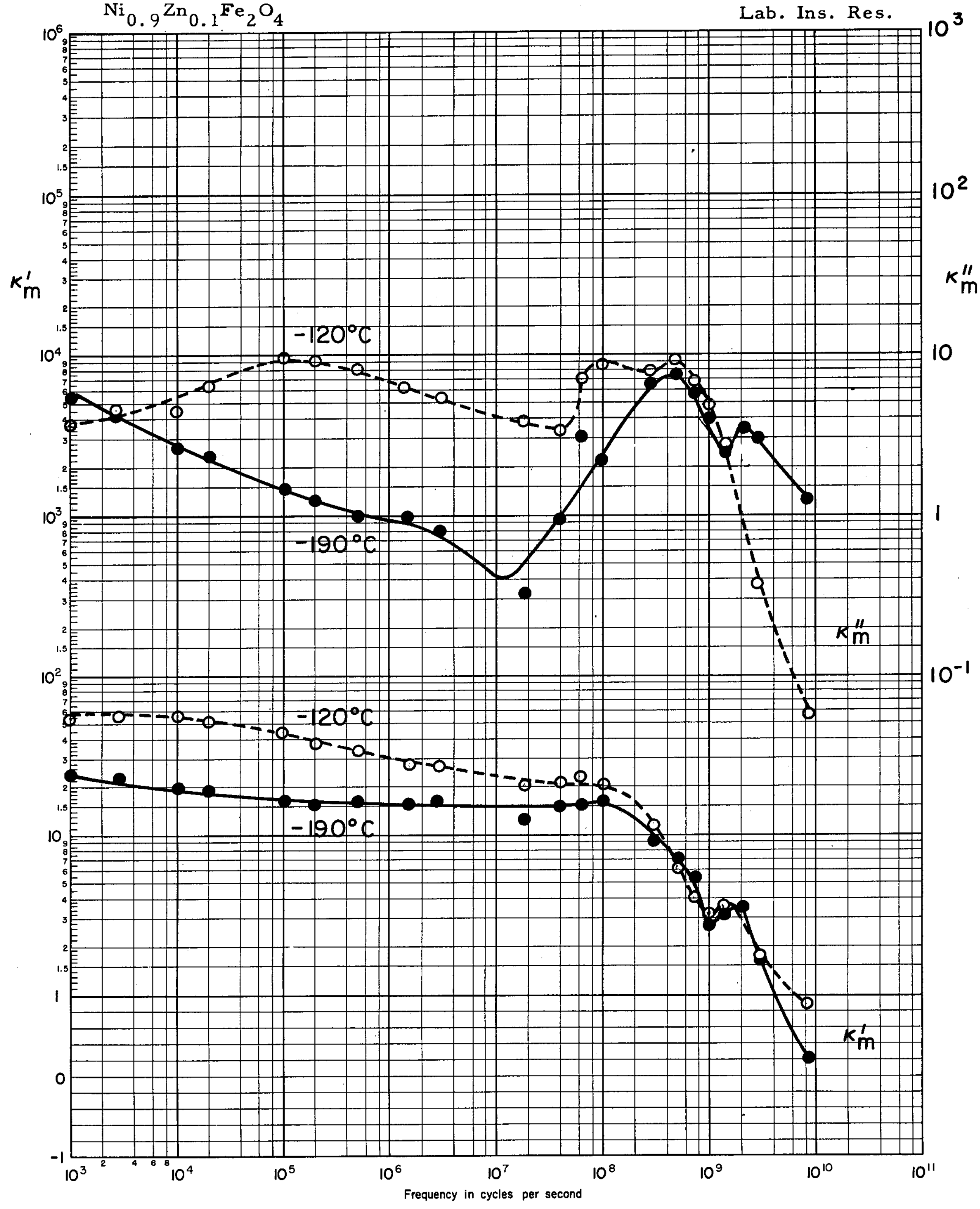
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.9}Zn_{0.1}Fe_2O_4$ Lab. Ins. Res.



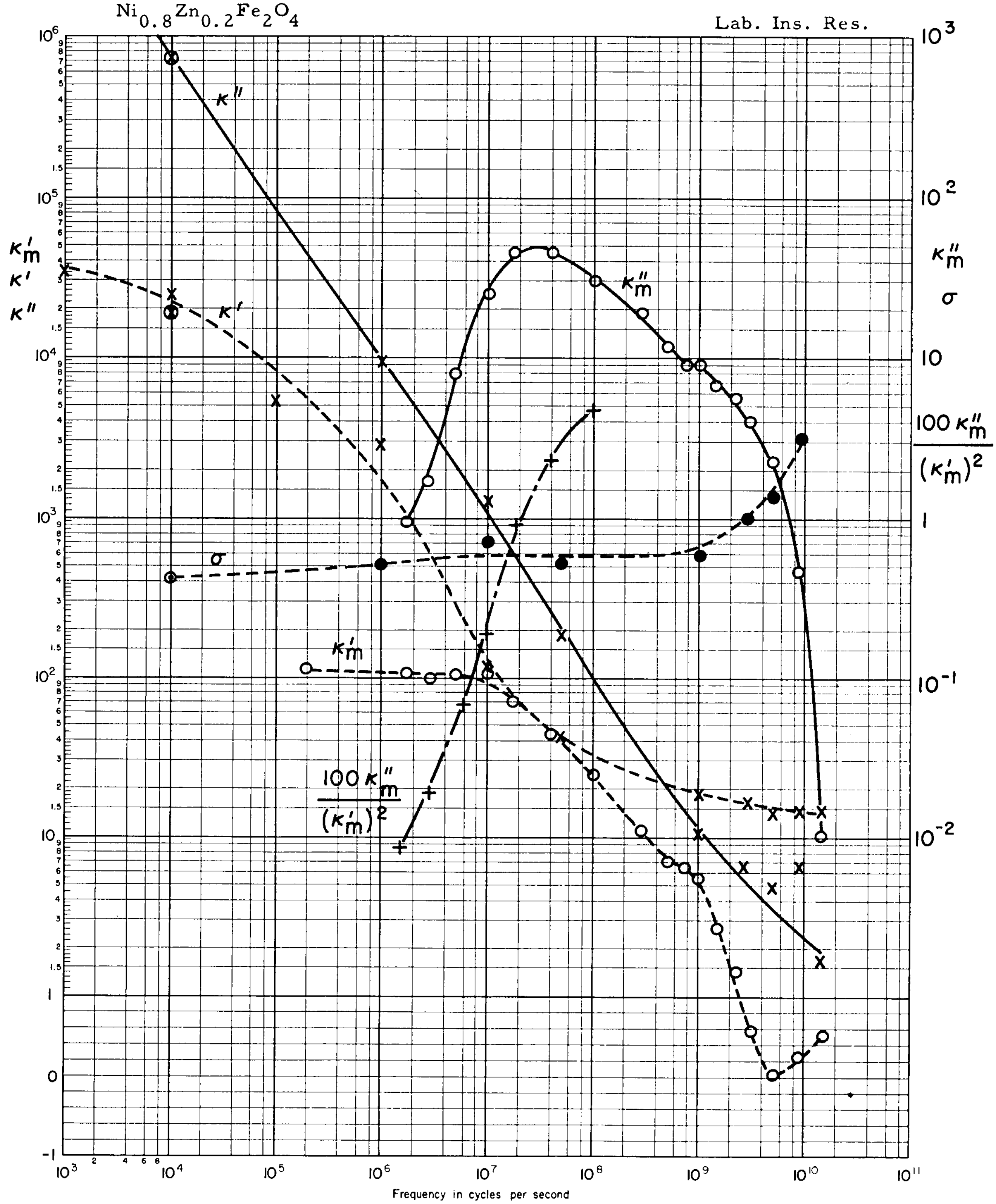
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.9}Zn_{0.1}Fe_2O_4$ Lab. Ins. Res.

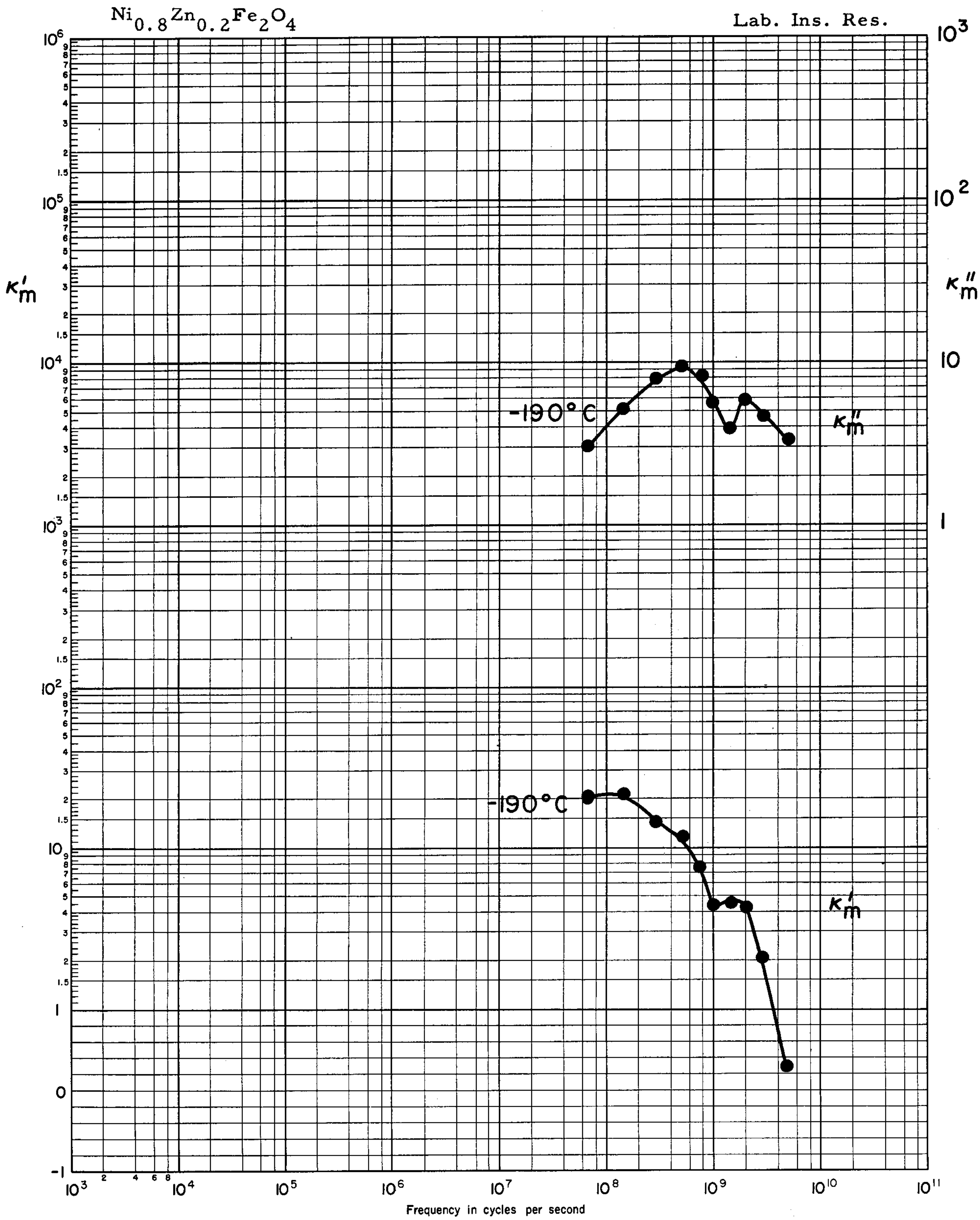


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.8}Zn_{0.2}Fe_2O_4$

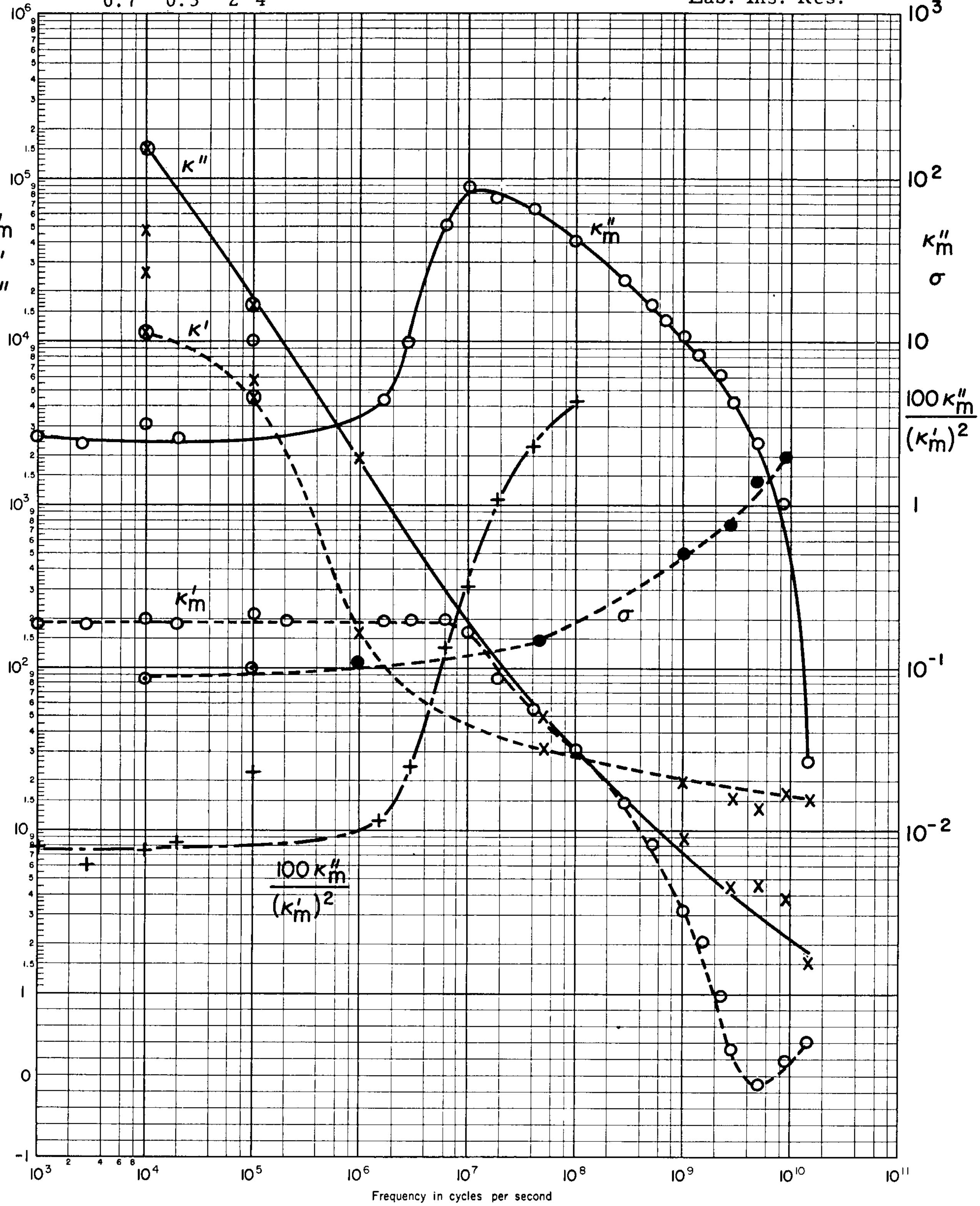


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



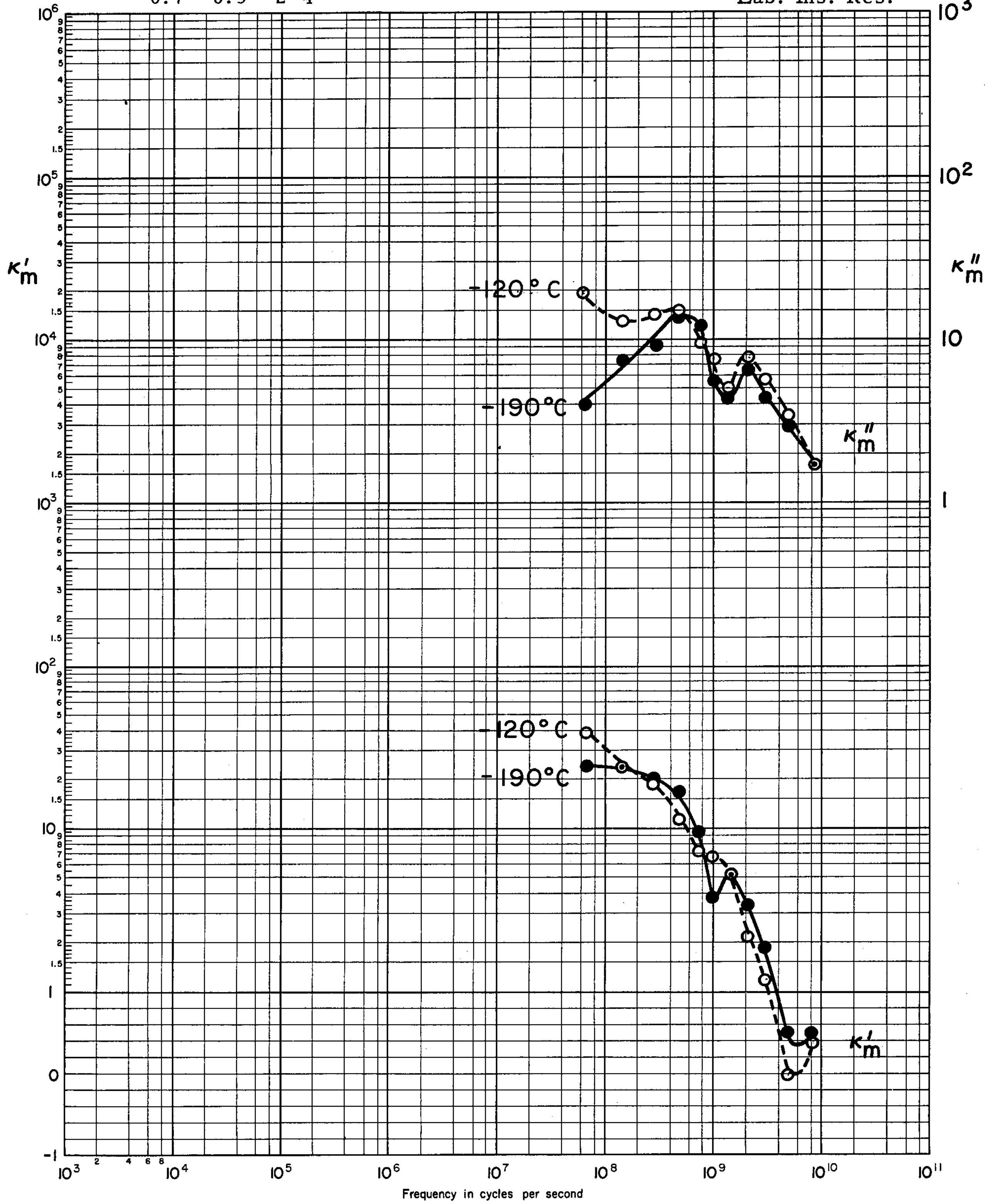
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.7}Zn_{0.3}Fe_2O_4$ Lab. Ins. Res.



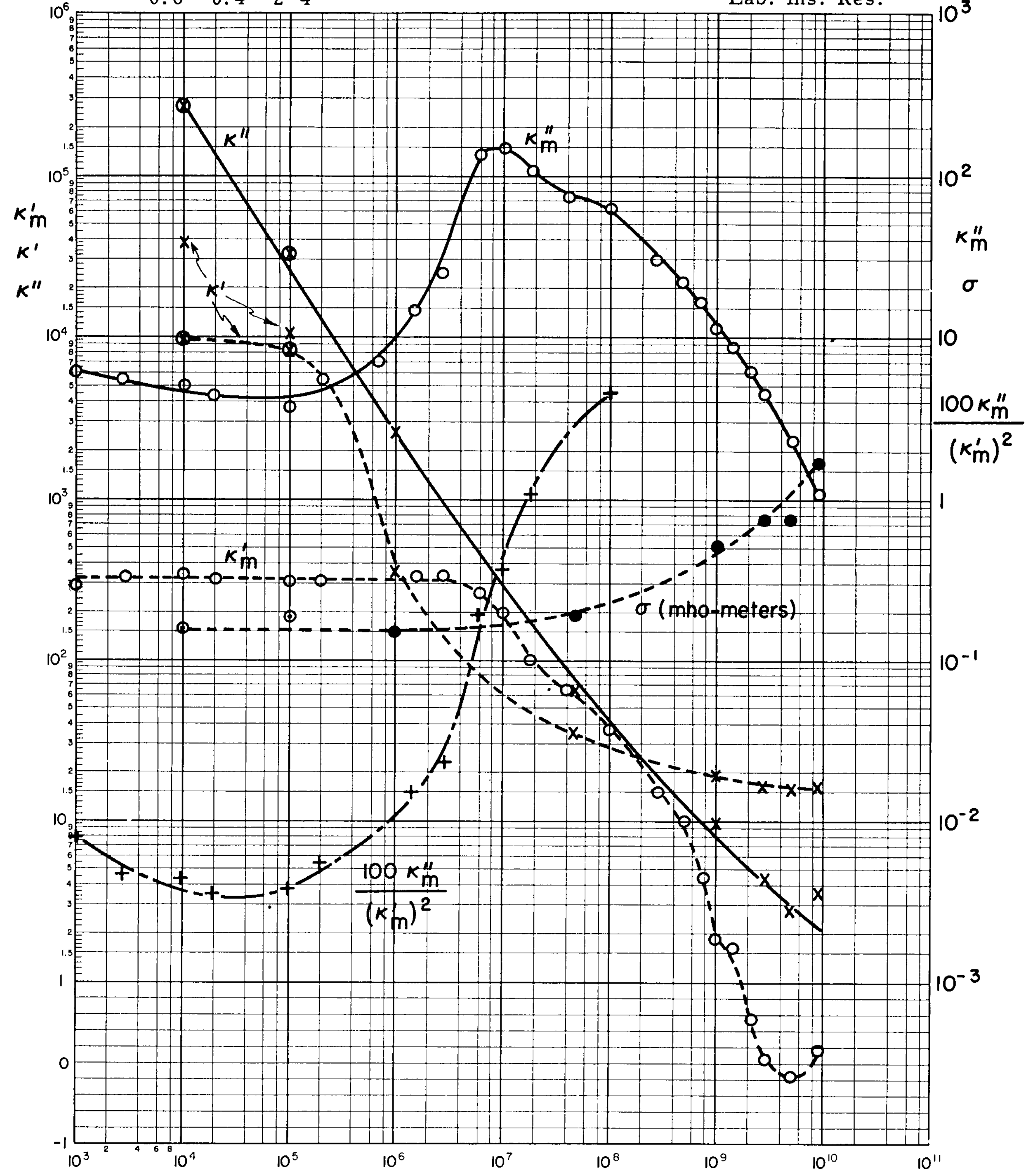
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.7}Zn_{0.3}Fe_2O_4$ Lab. Ins. Res.

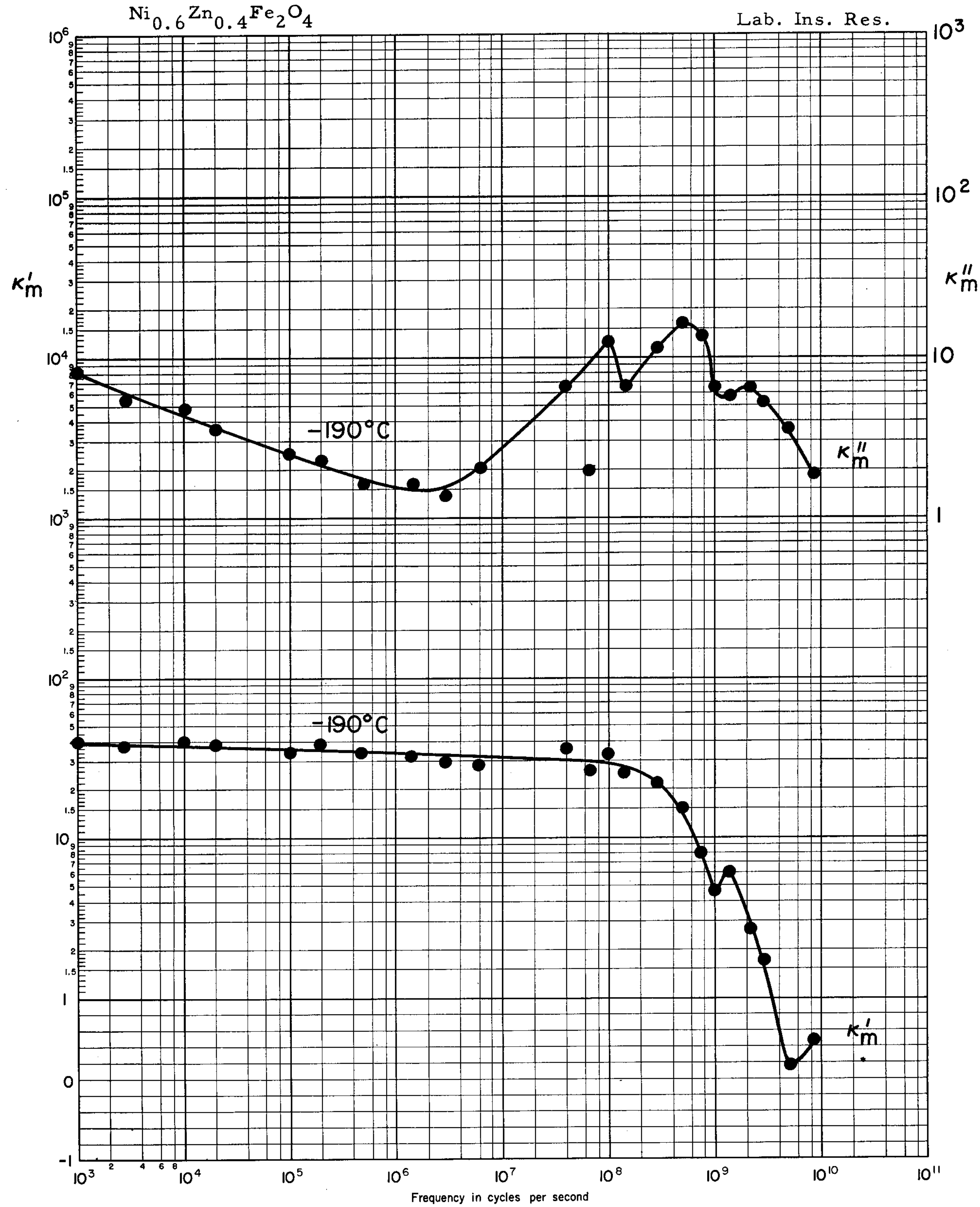


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.6}Zn_{0.4}Fe_2O_4$ Lab. Ins. Res.



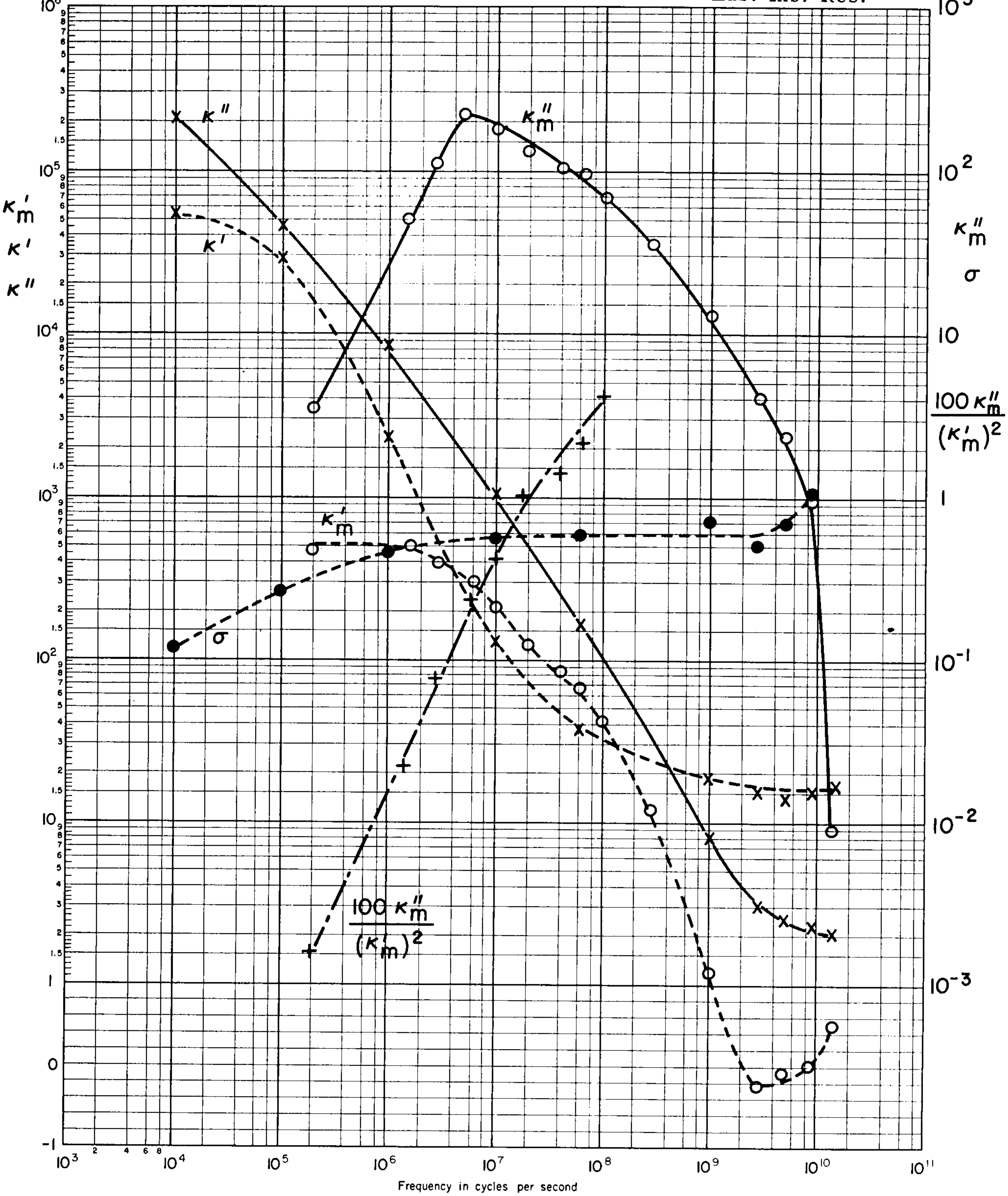
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



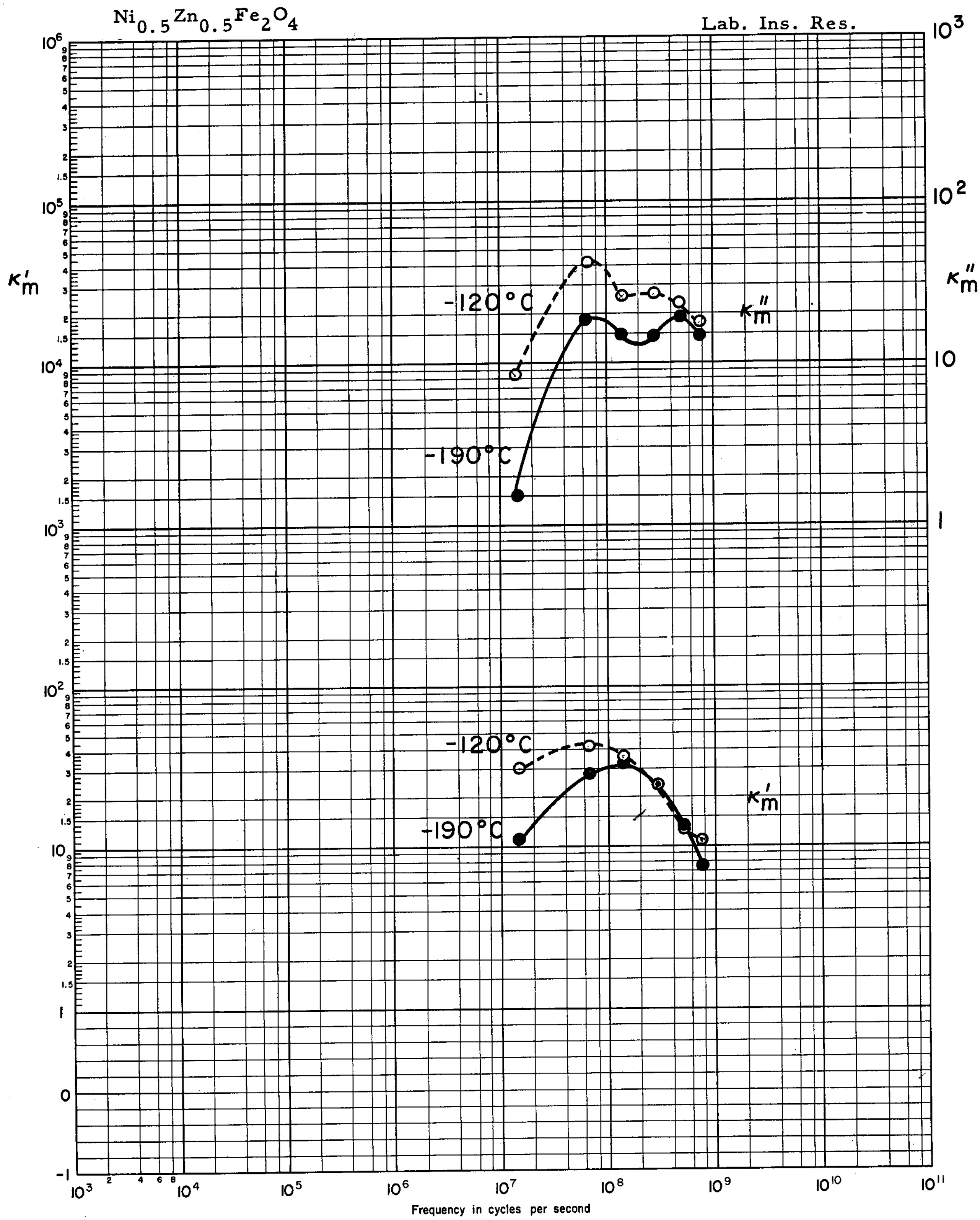
IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.5}Zn_{0.5}Fe_2O_4$

Lab. Ins. Res.



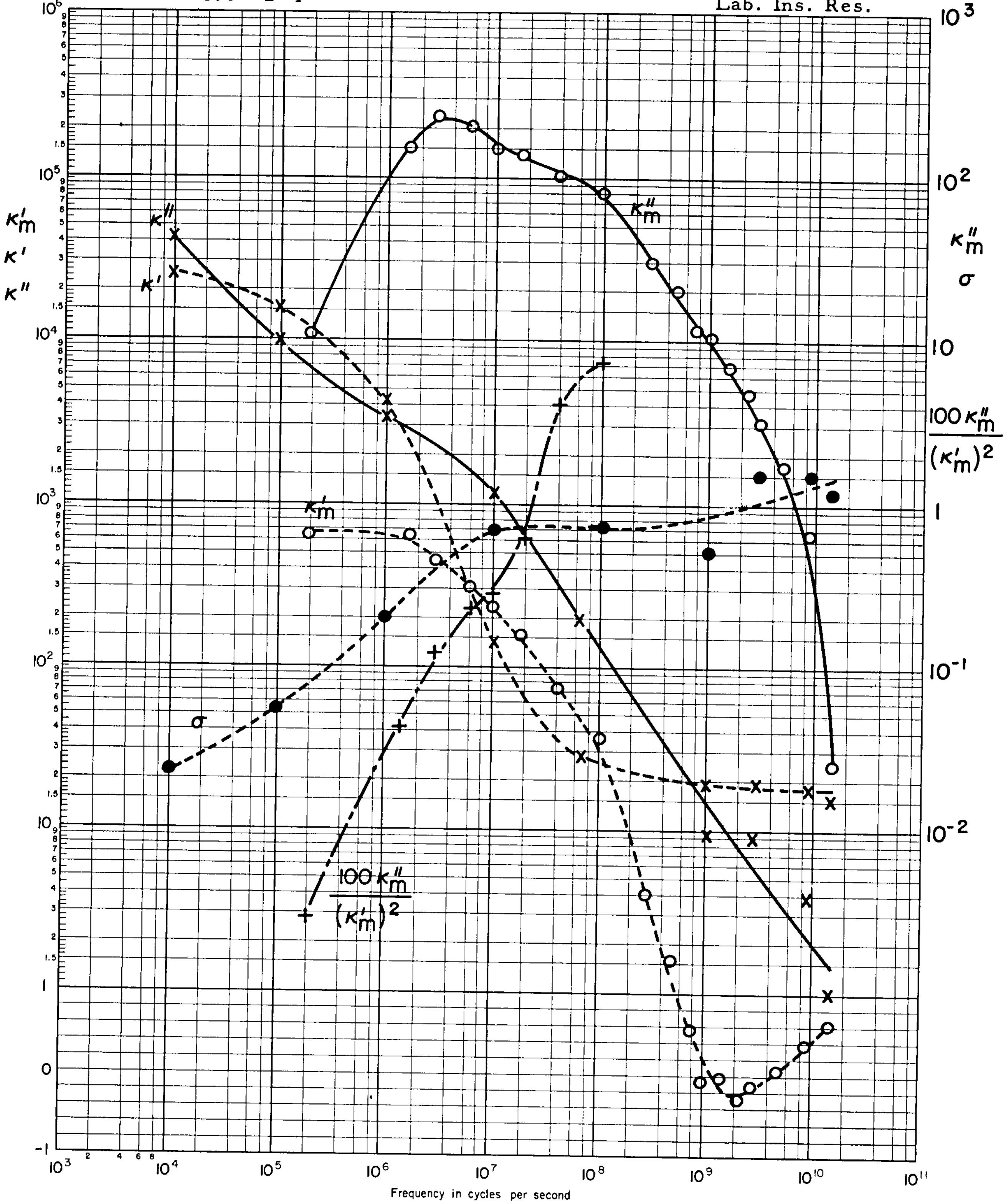
IV A.8. Nickel-Zinc Ferrites, High Density Ceramics



IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

$Ni_{0.4}Zn_{0.6}Fe_2O_4$

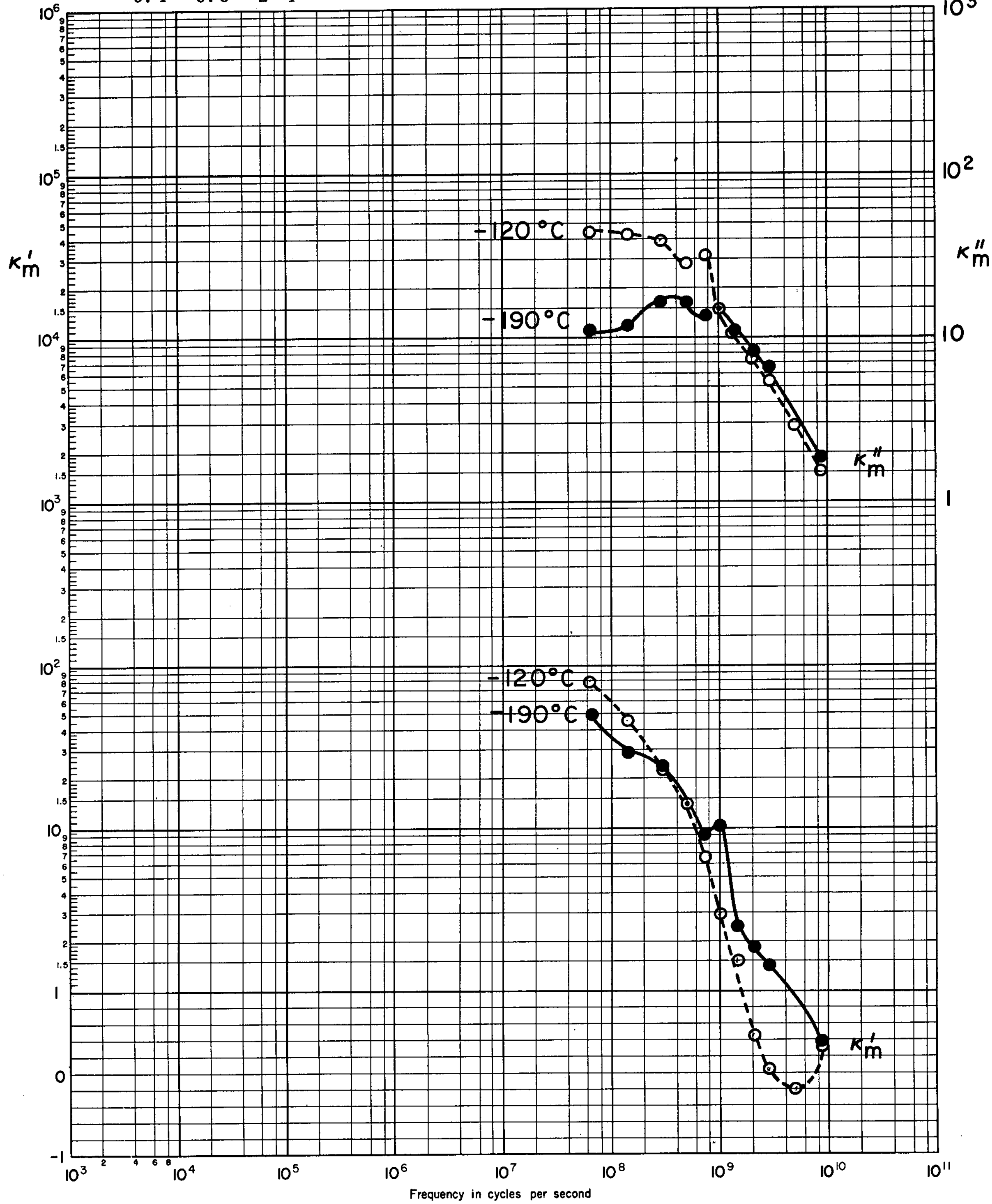
Lab. Ins. Res.



IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

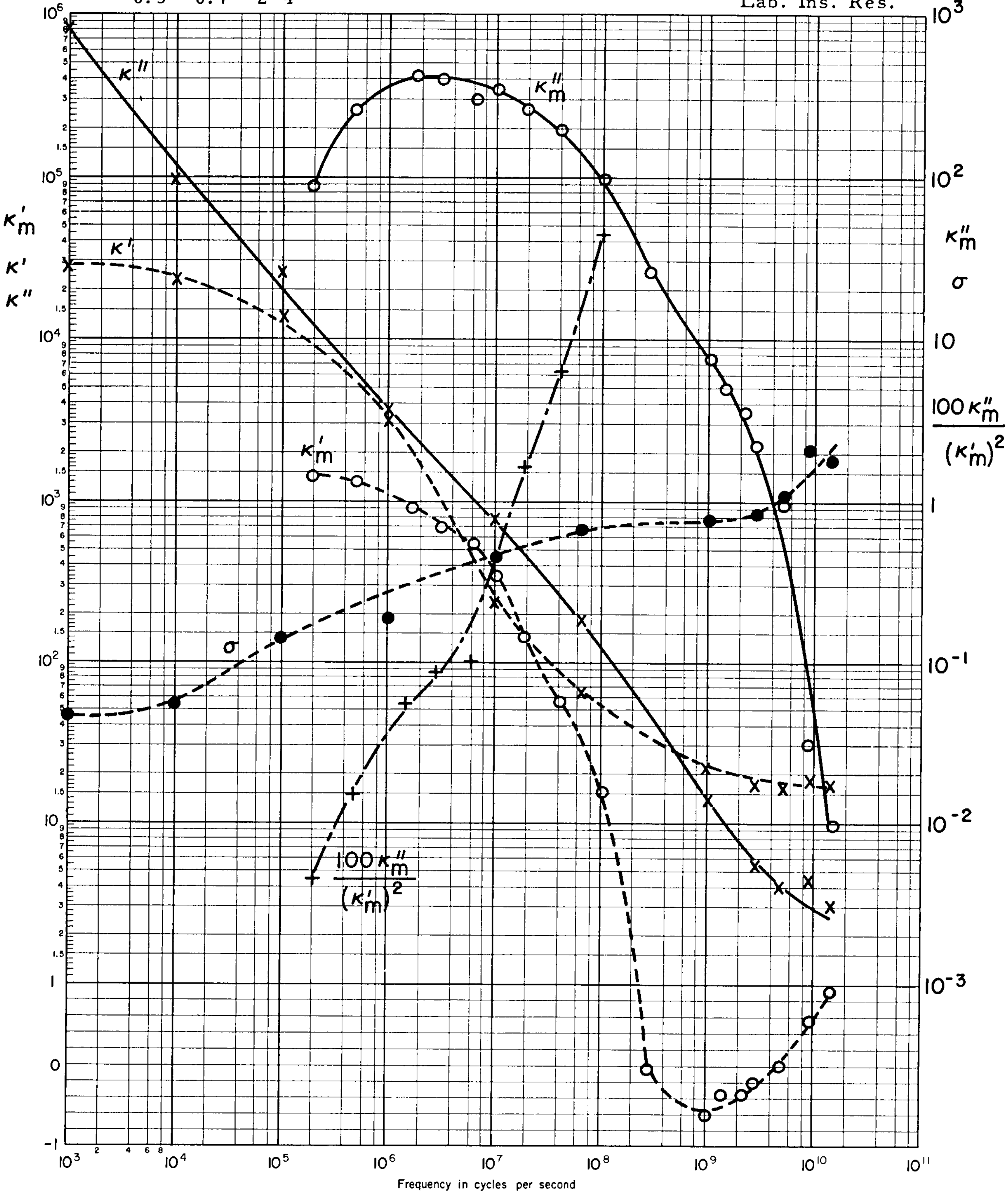
$Ni_{0.4}Zn_{0.6}Fe_2O_4$

Lab. Ins. Res.

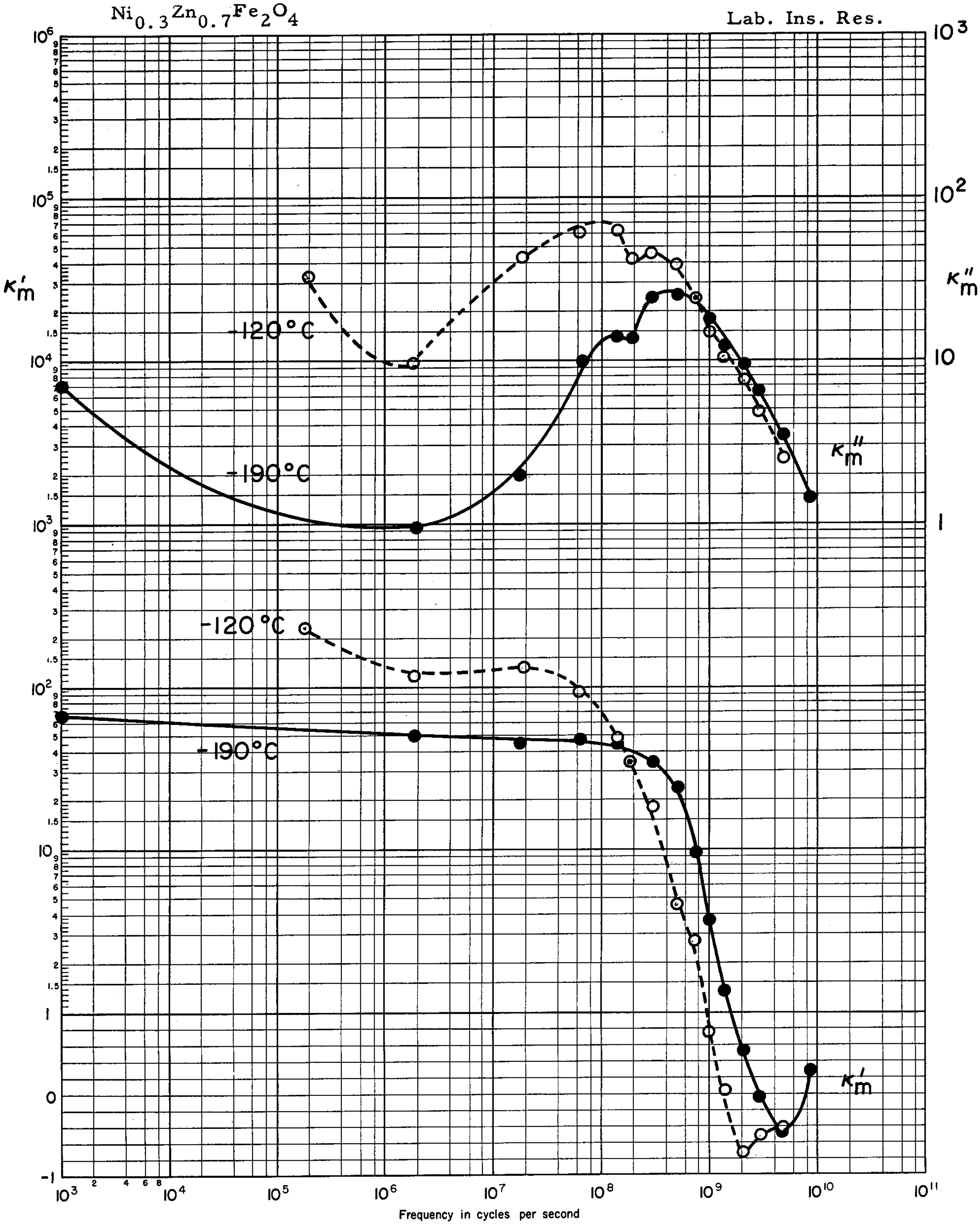


IV A 8. Nickel-Zinc Ferrites, High Density Ceramics

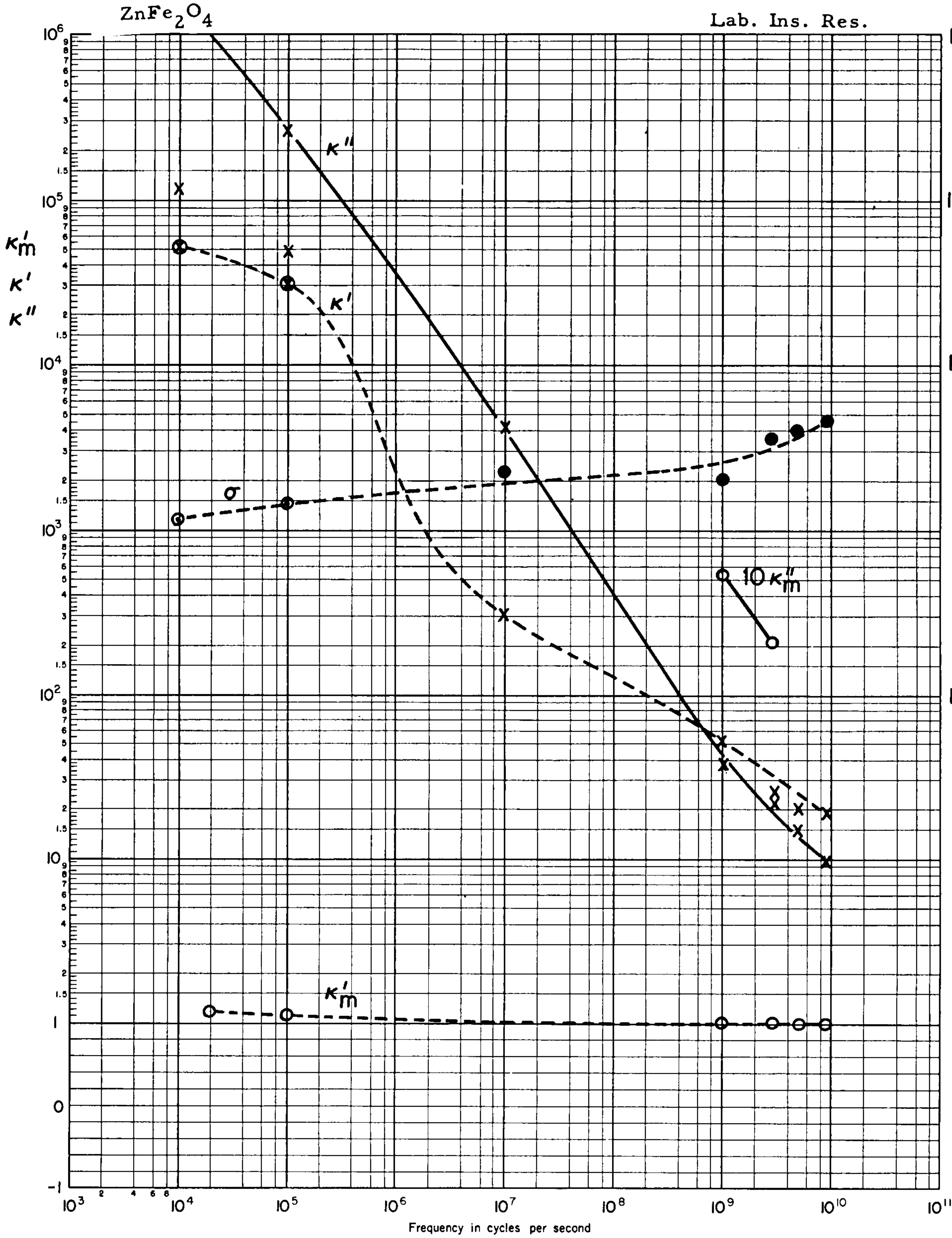
$Ni_{0.3}Zn_{0.7}Fe_2O_4$ Lab. Ins. Res.



IV A 8. Nickel-Zinc Ferrites, High Density Ceramics



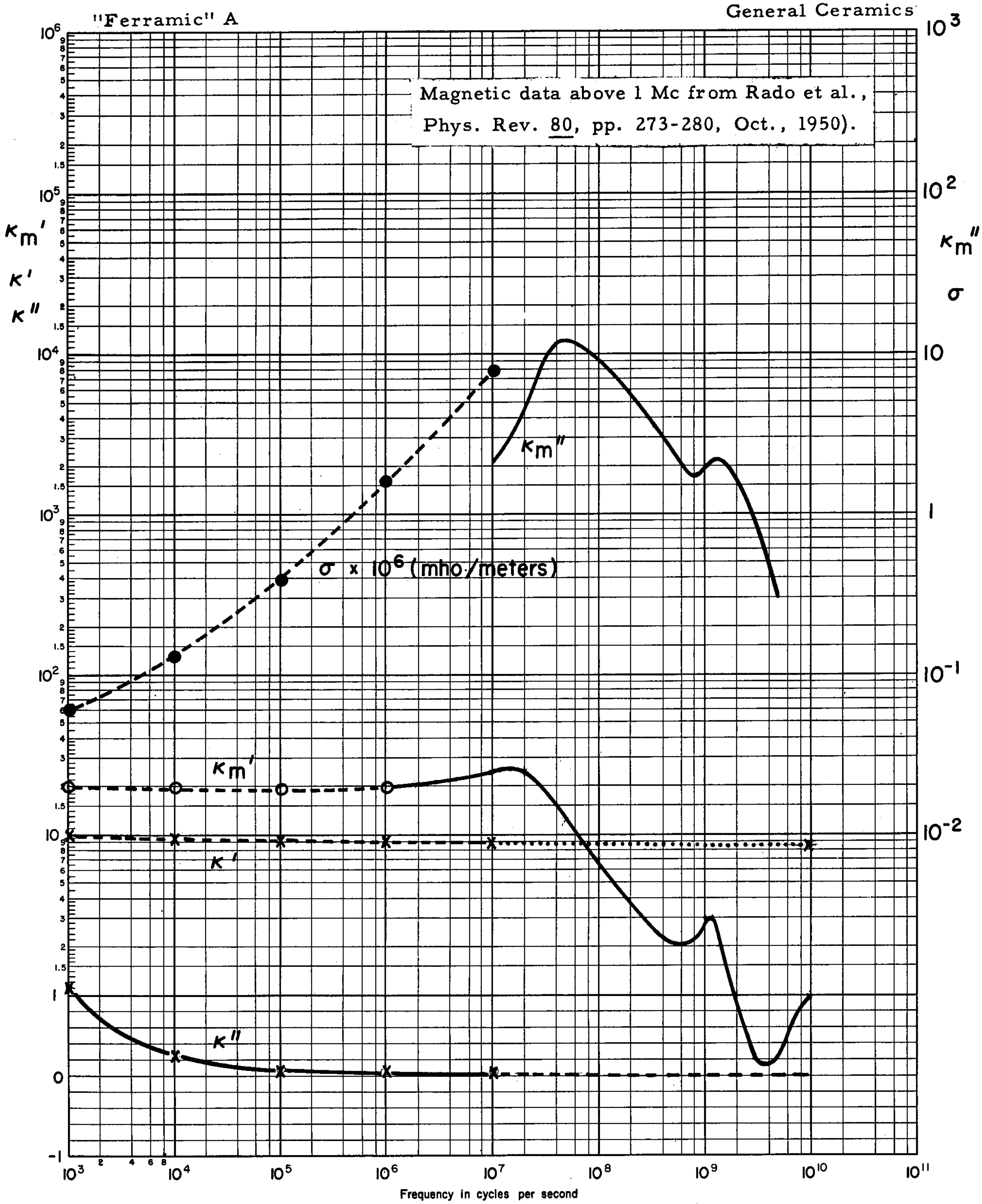
IV A 9. Zinc Ferrite, High Density Ceramic



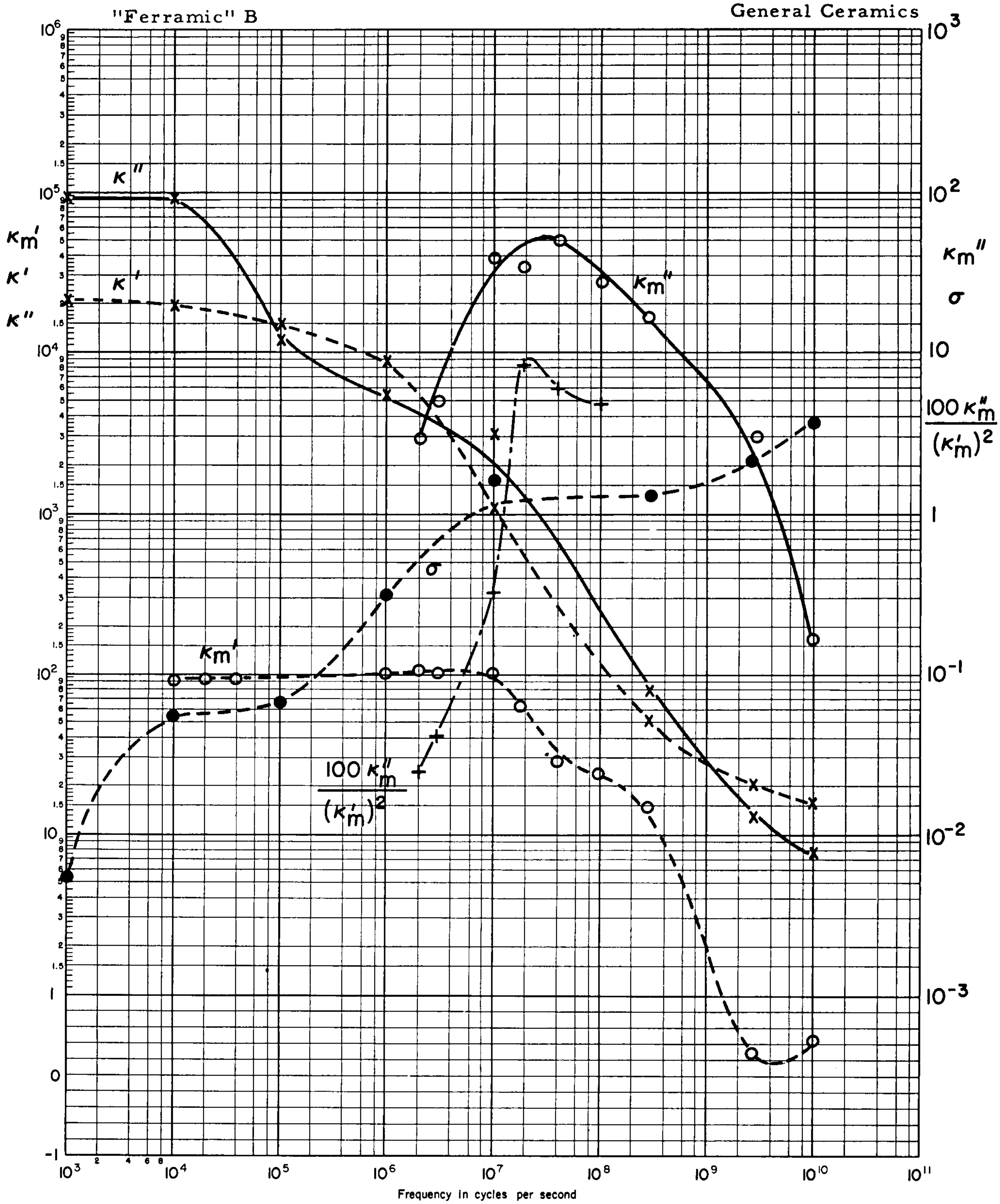
IV A 10. Commercial Ferrites

"Ferramic" A

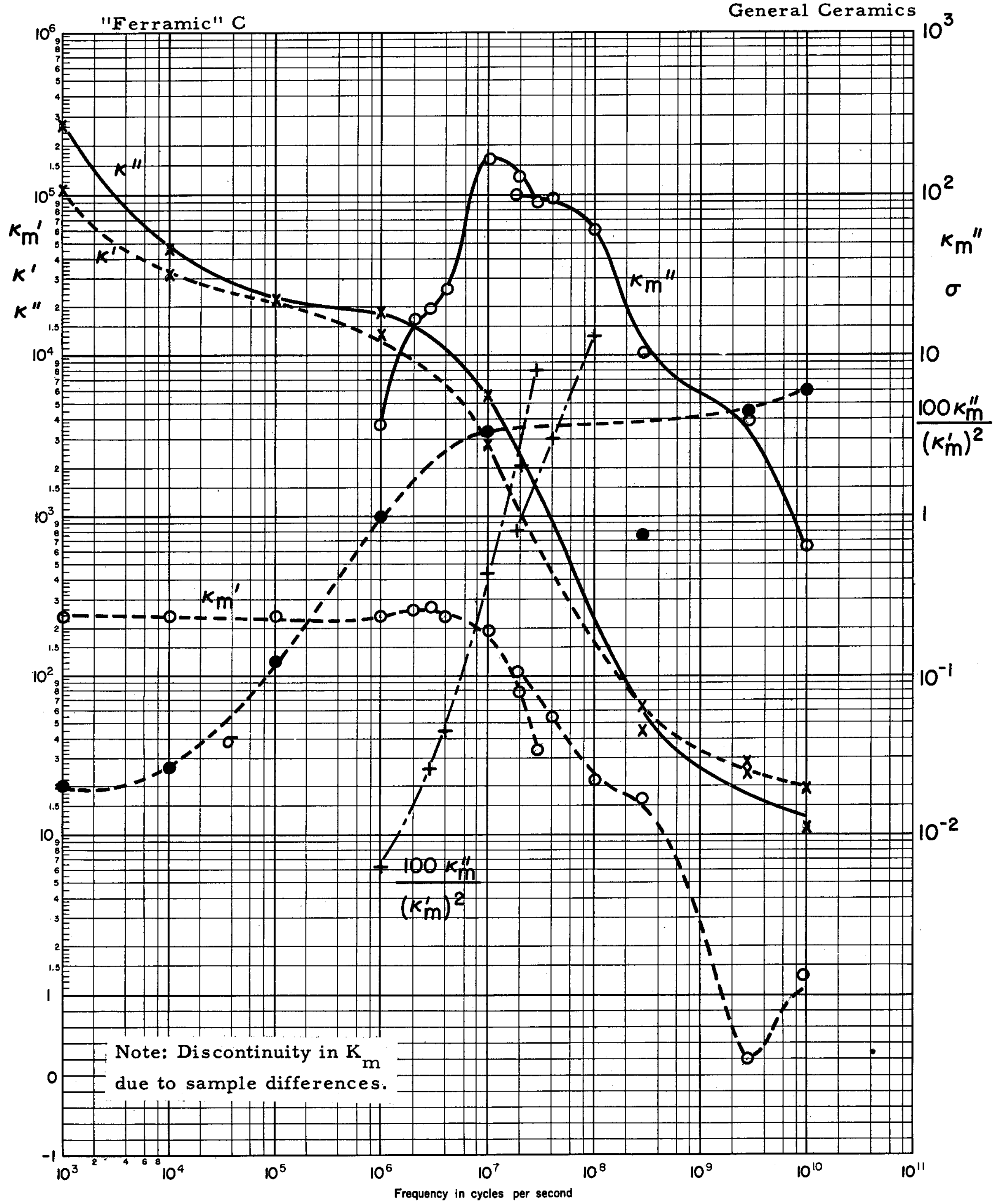
General Ceramics



IV A 10. Commercial Ferrites



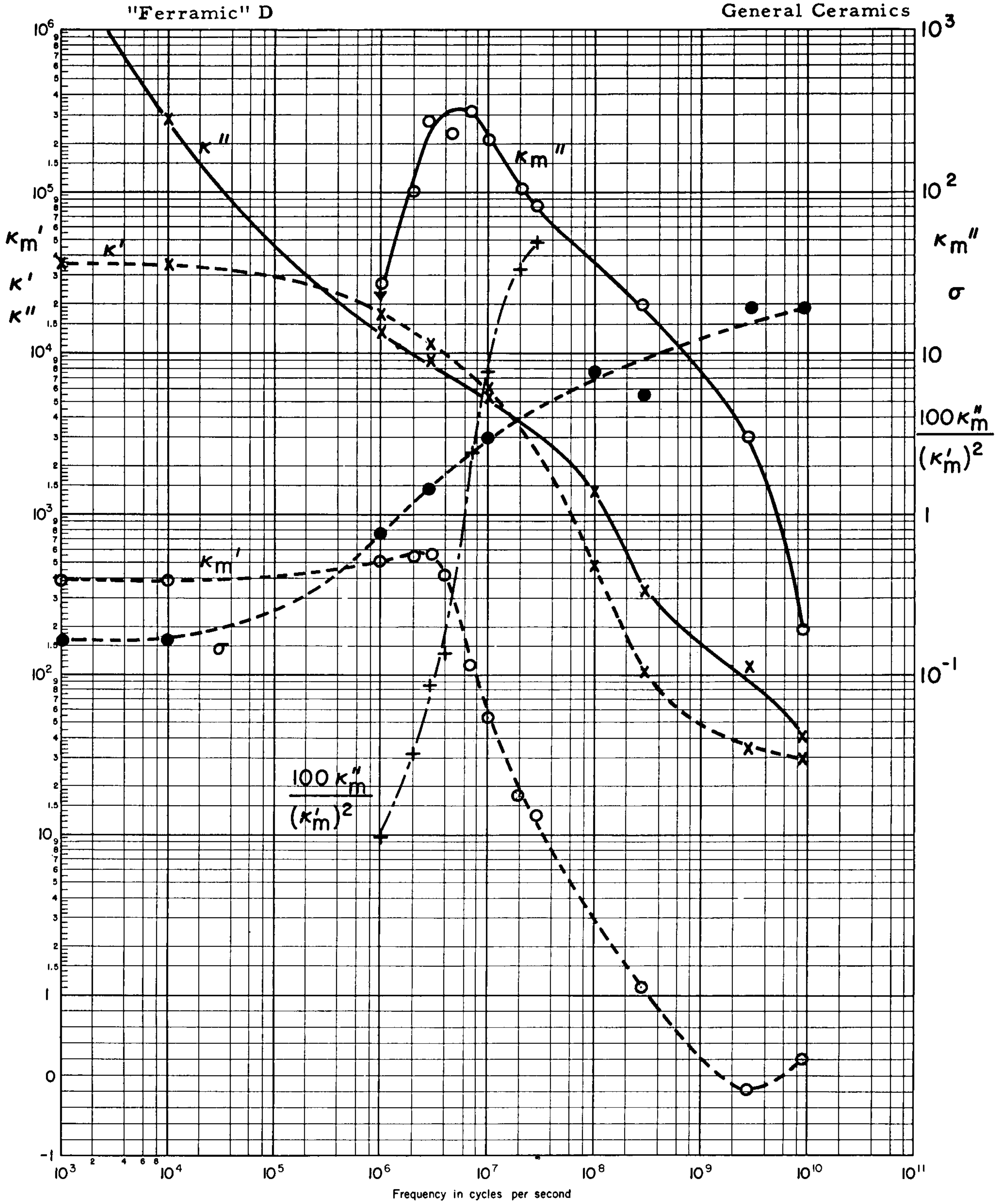
IV A 10. Commercial Ferrites



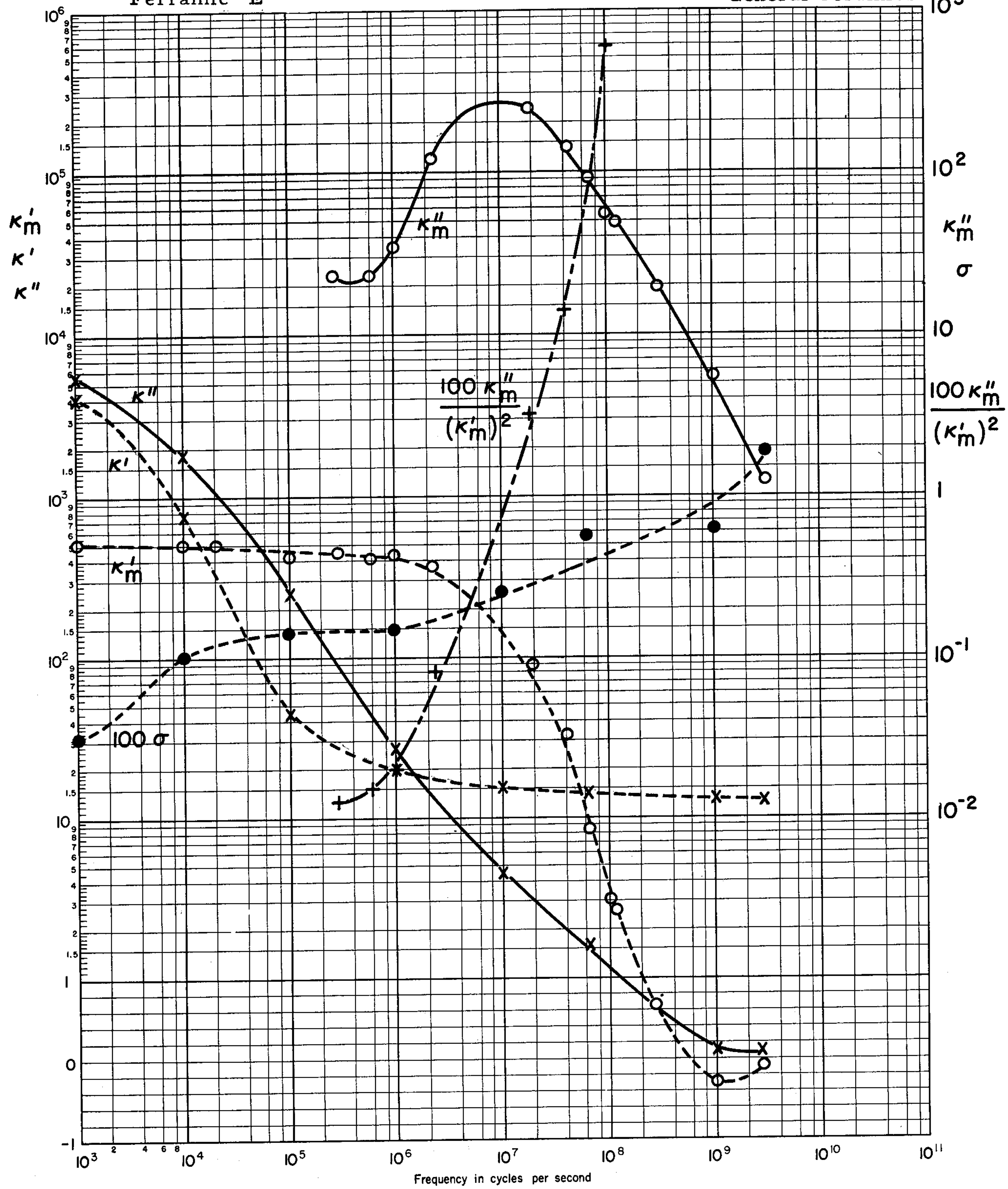
IV A 10. Commercial Ferrites

"Ferramic" D

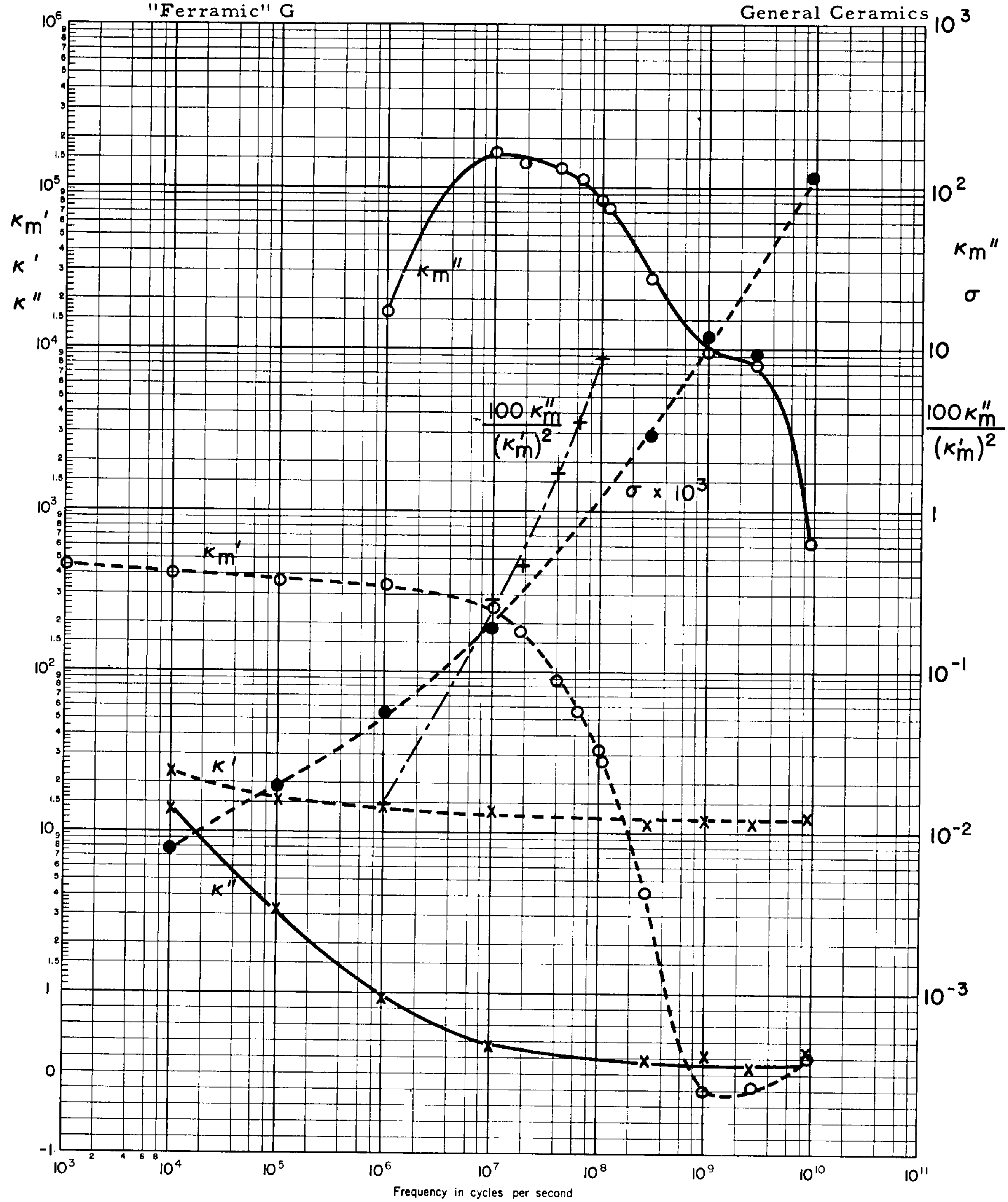
General Ceramics



"Ferramic" E — IV A 10. Commercial Ferrites — General Ceramics



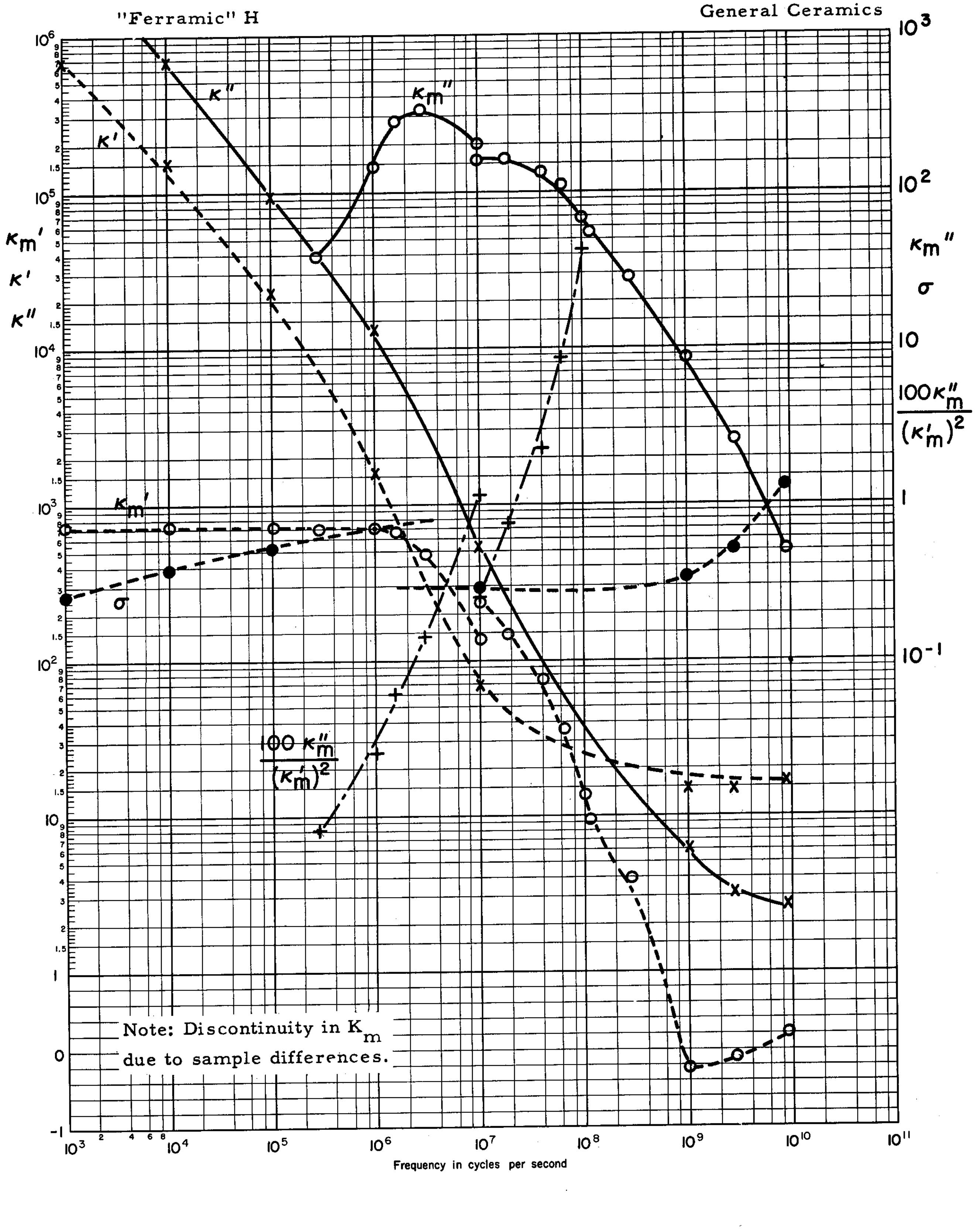
IV A 10. Commercial Ferrites



IV A 10. Commercial Ferrites

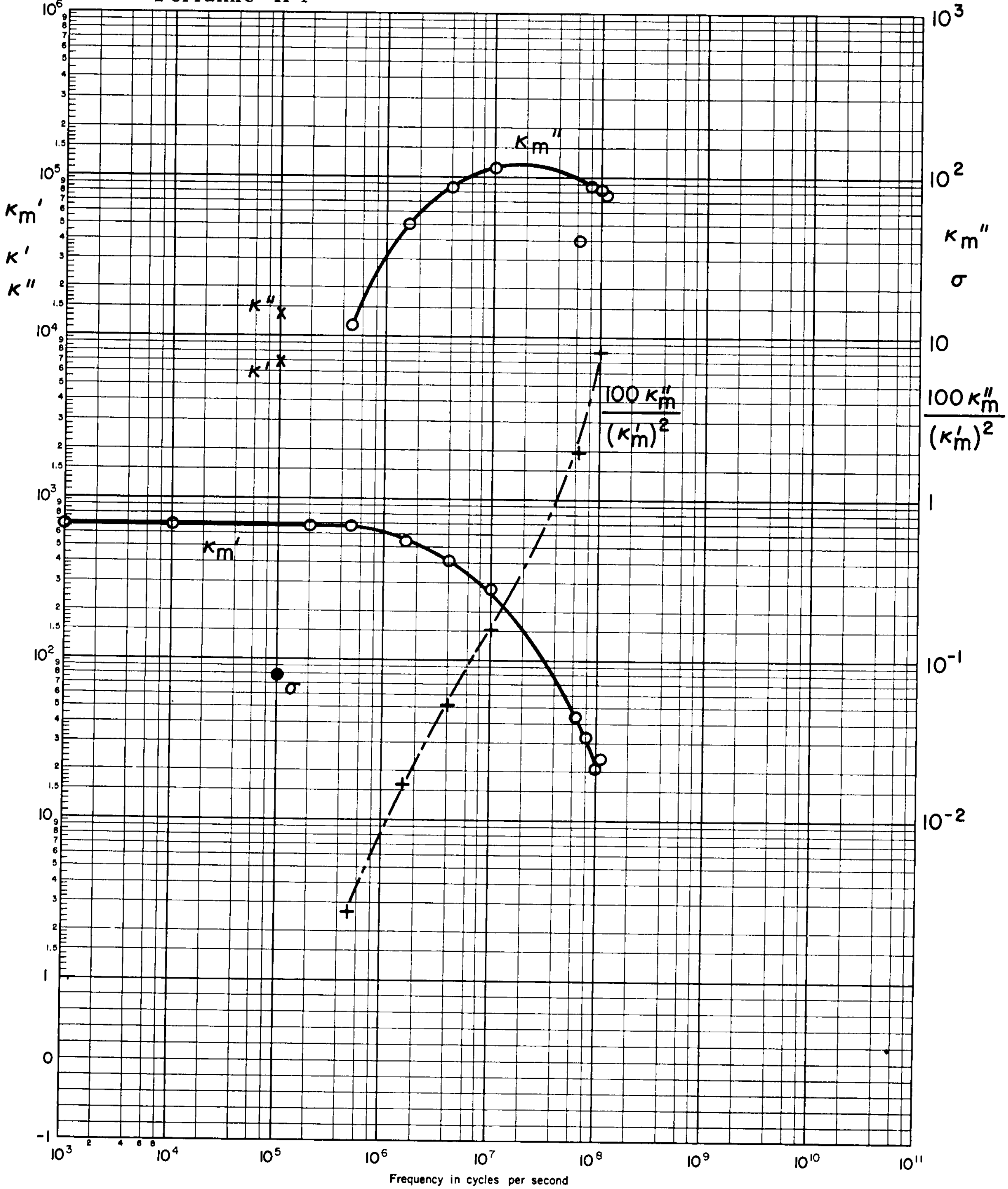
"Ferramic" H

General Ceramics

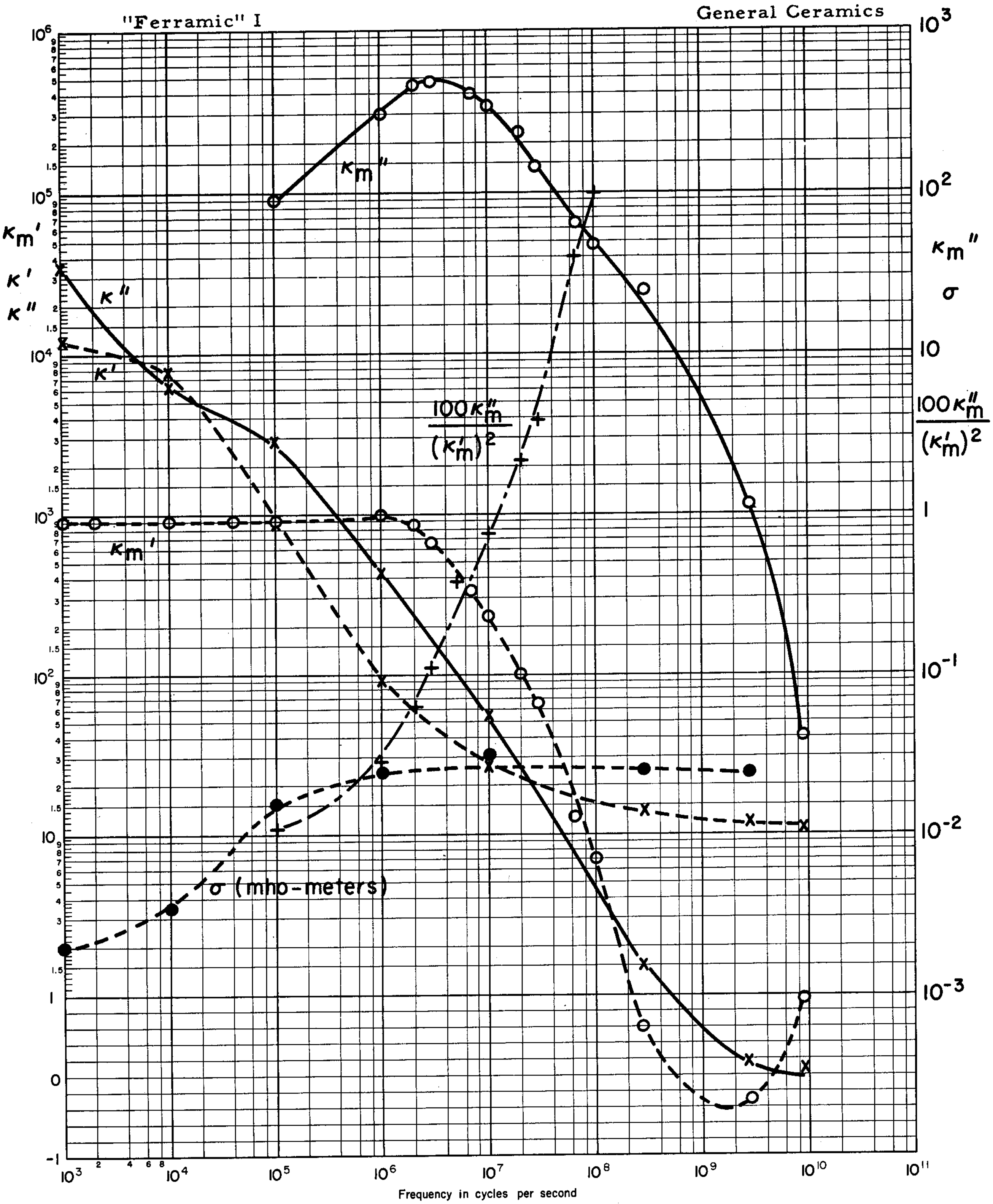


IV A 10. Commercial Ferrites

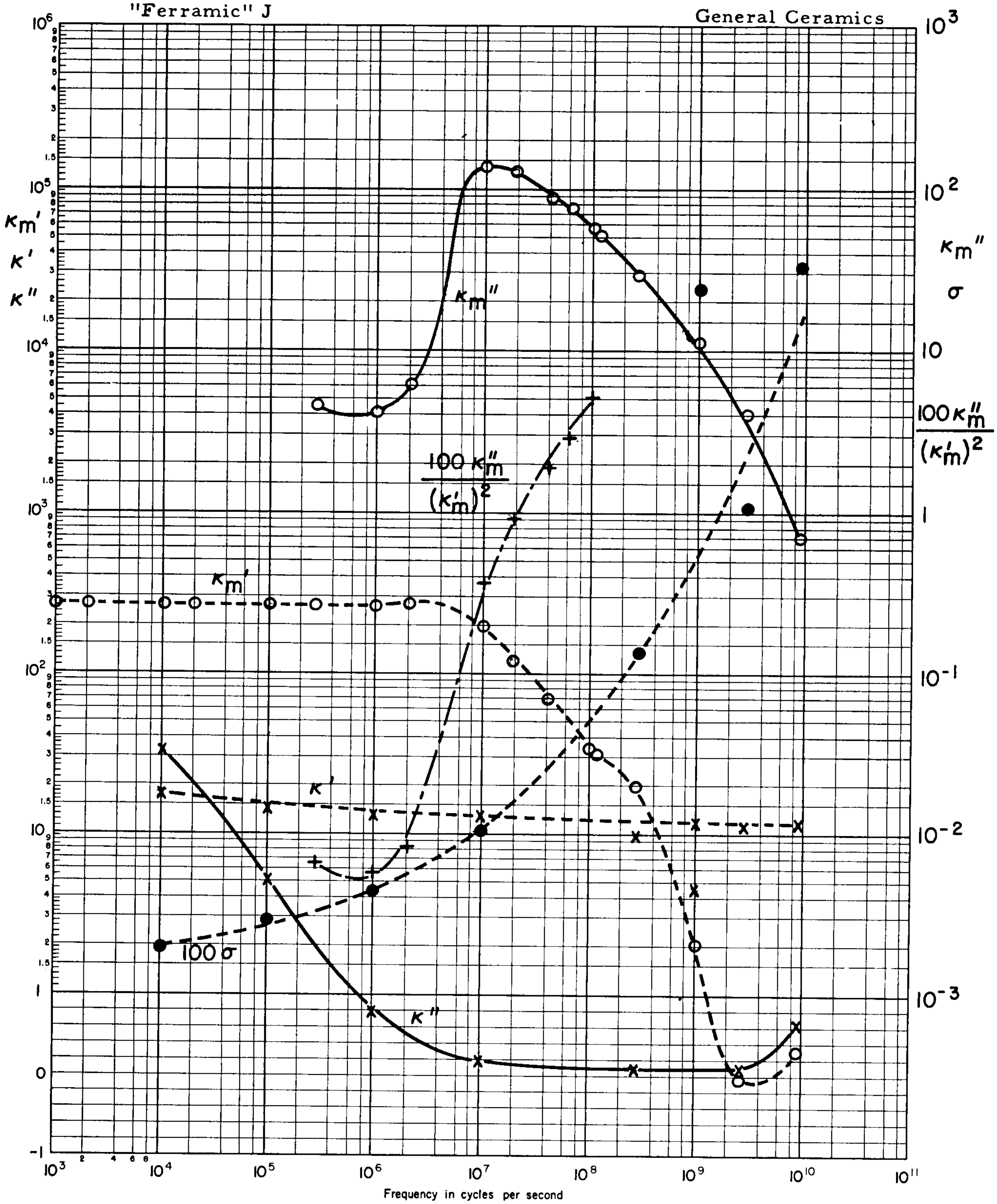
"Ferramic" H-1 General Ceramics



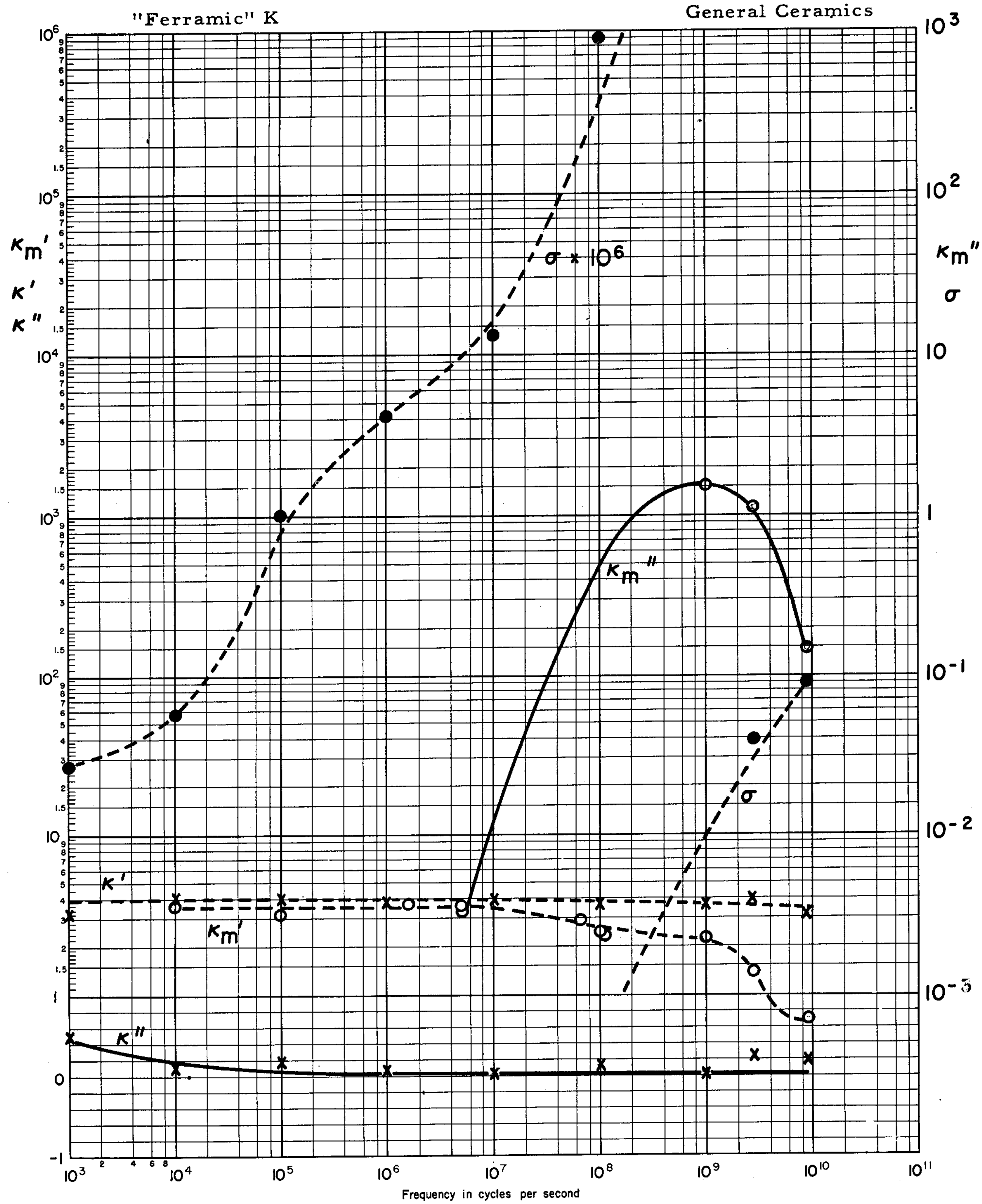
IV A 10. Commercial Ferrites



IV A 10. Commercial Ferrites

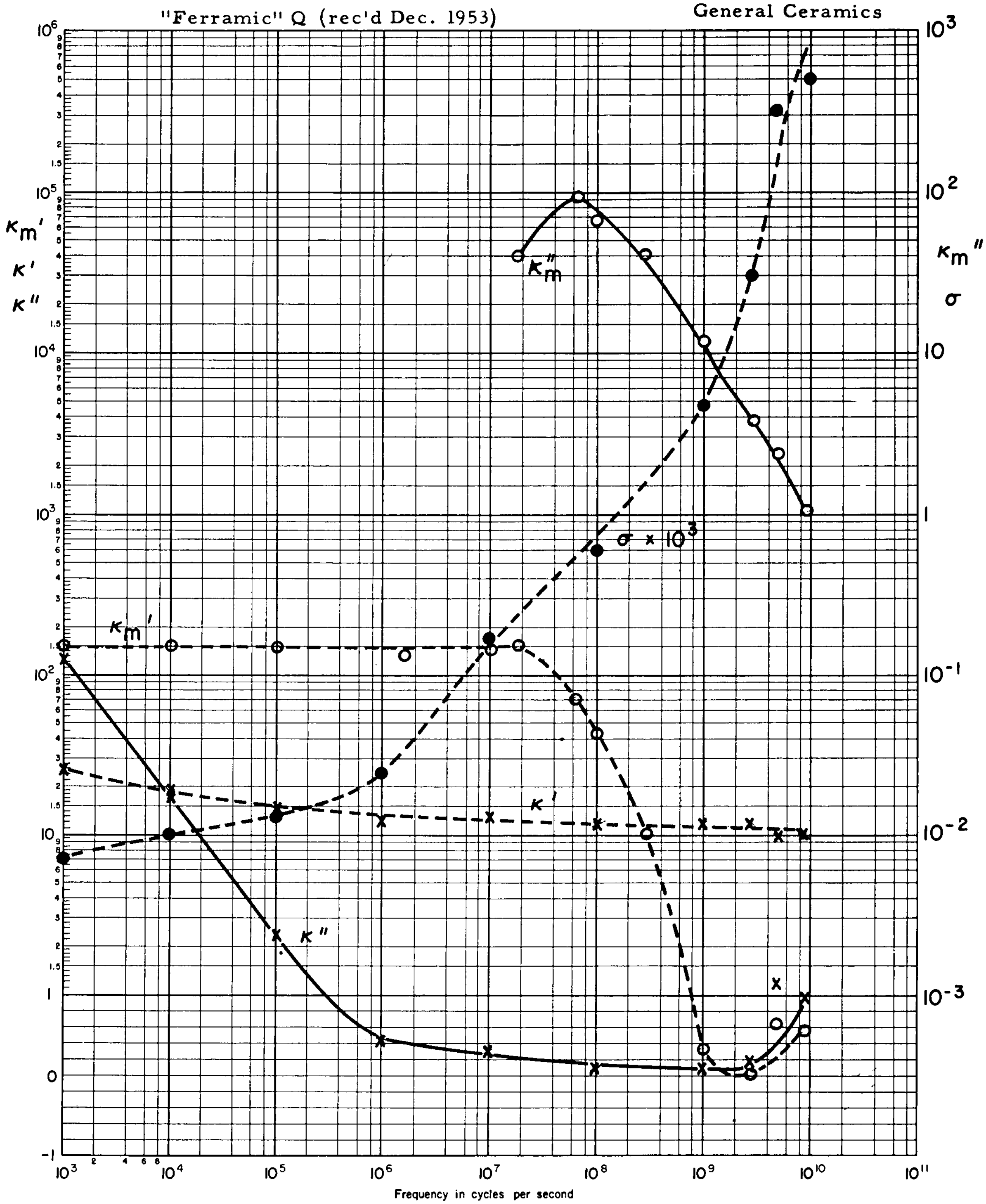


IV A 10. Commercial Ferrites



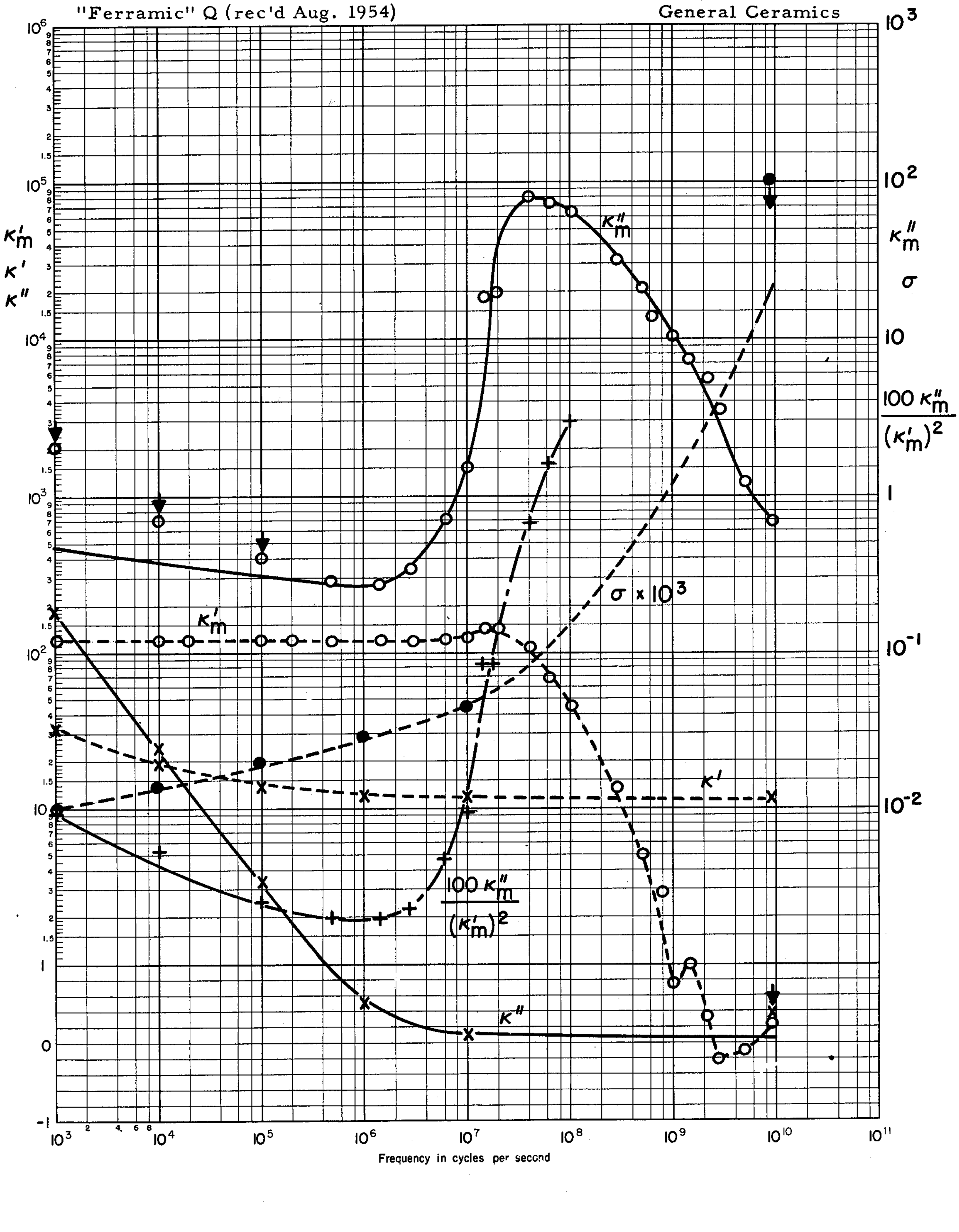
IV A 10. Commercial Ferrites

"Ferramic" Q (rec'd Dec. 1953) General Ceramics



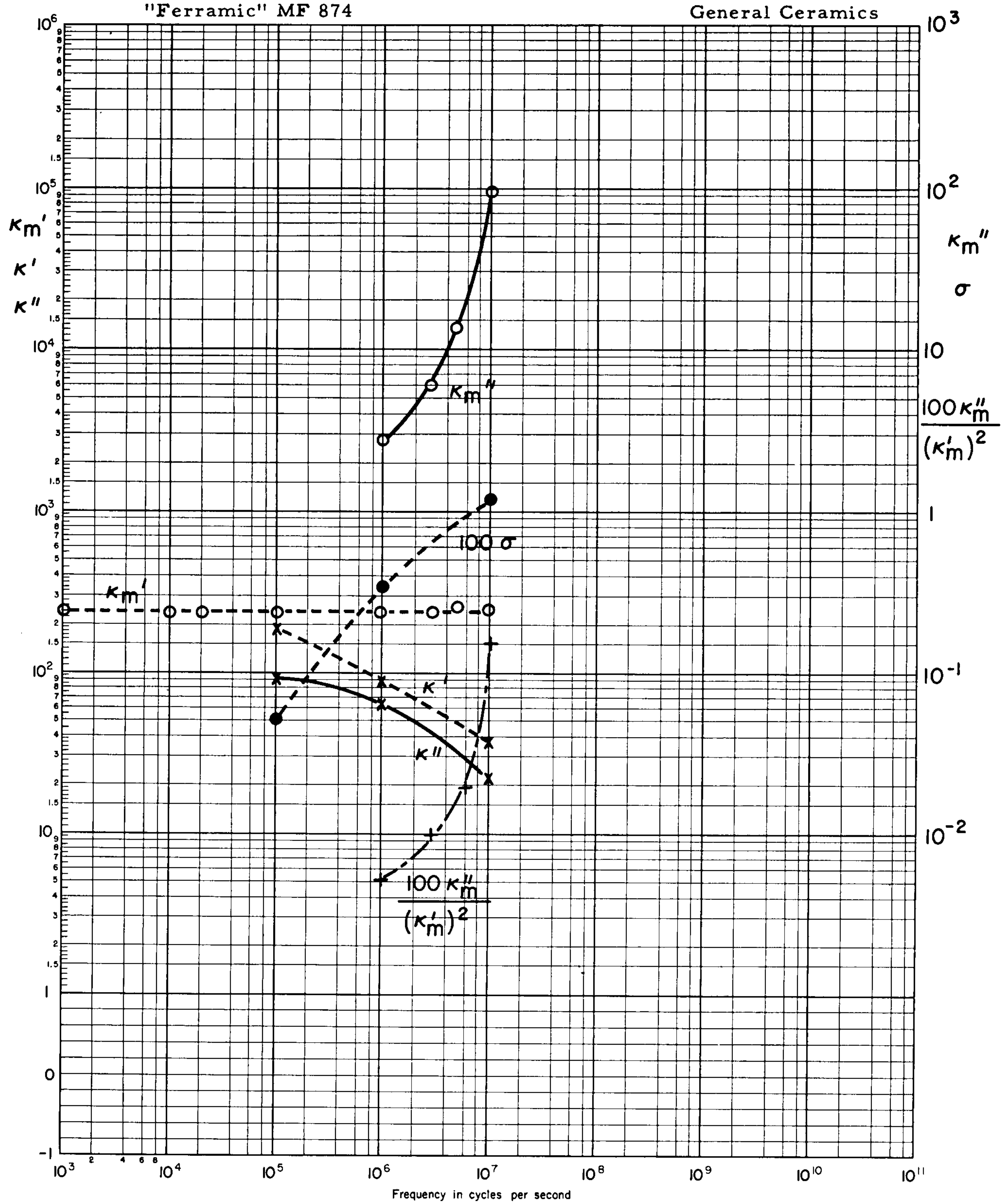
IV A 10. Commercial Ferrites

"Ferramic" Q (rec'd Aug. 1954) General Ceramics

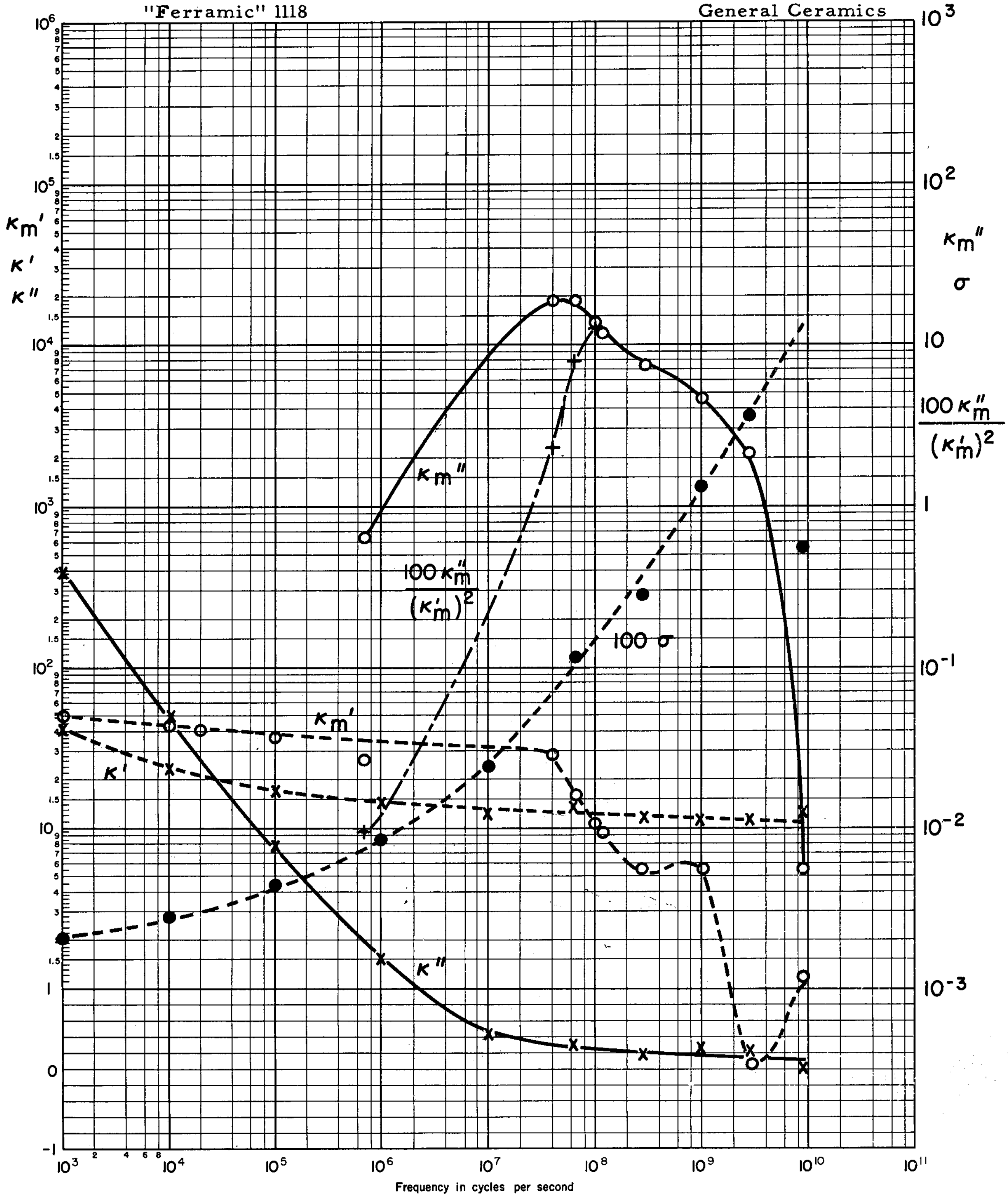


IV A 10. Commercial Ferrites

"Ferramic" MF 874 General Ceramics

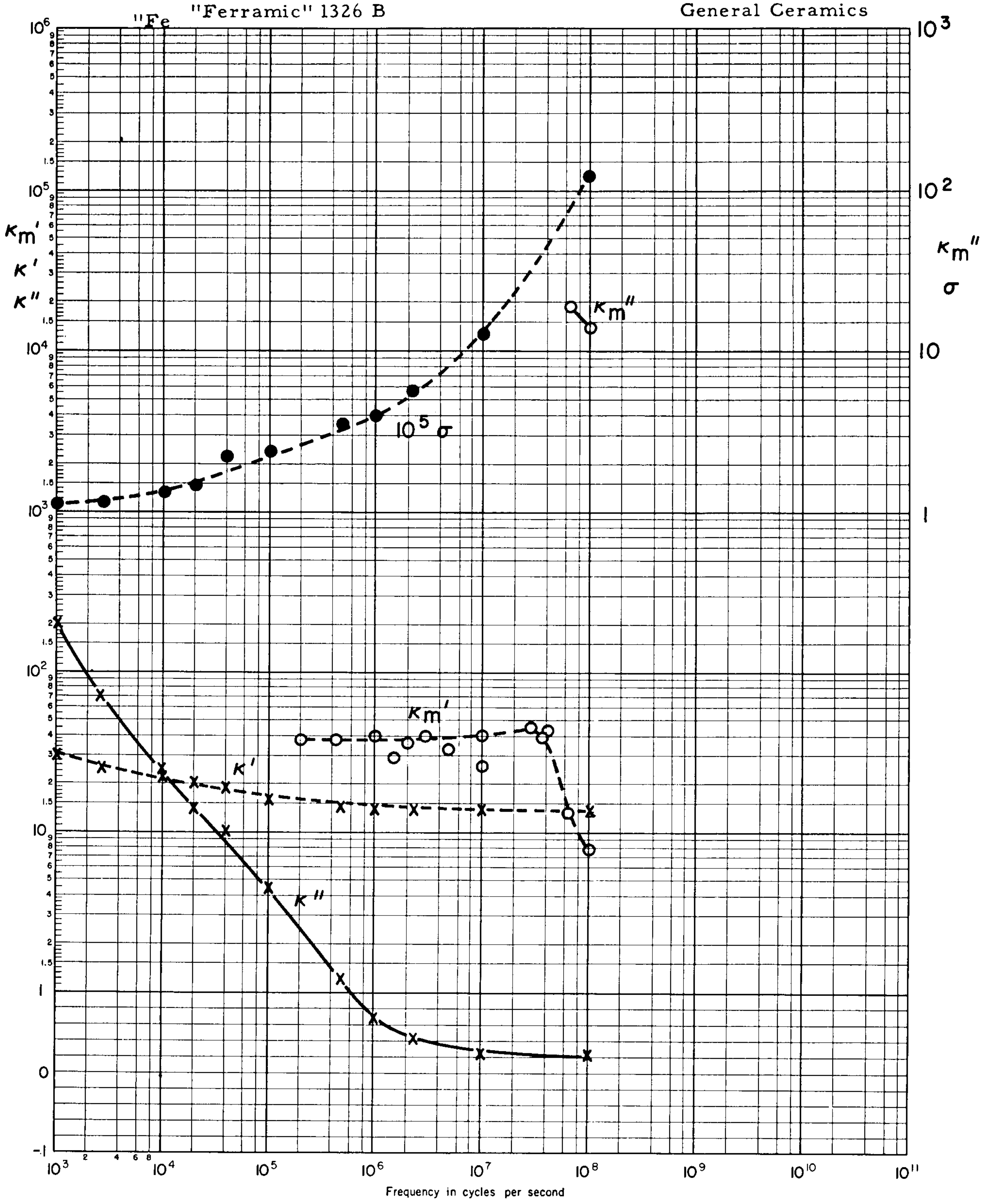


IV A 10. Commercial Ferrites



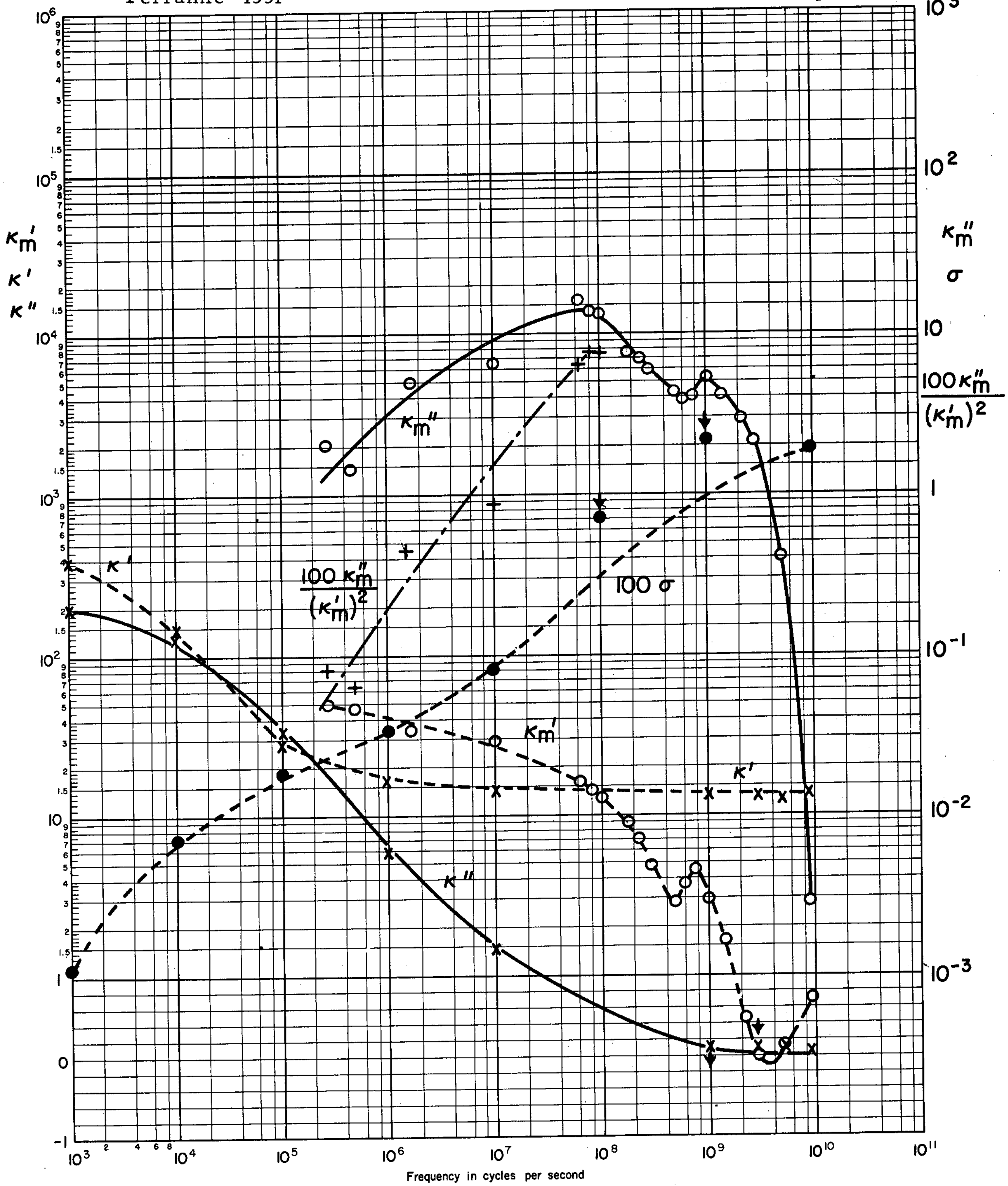
IV A 10. Commercial Ferrites

"Ferramic" 1326 B General Ceramics



IV A 10. Commercial Ferrites

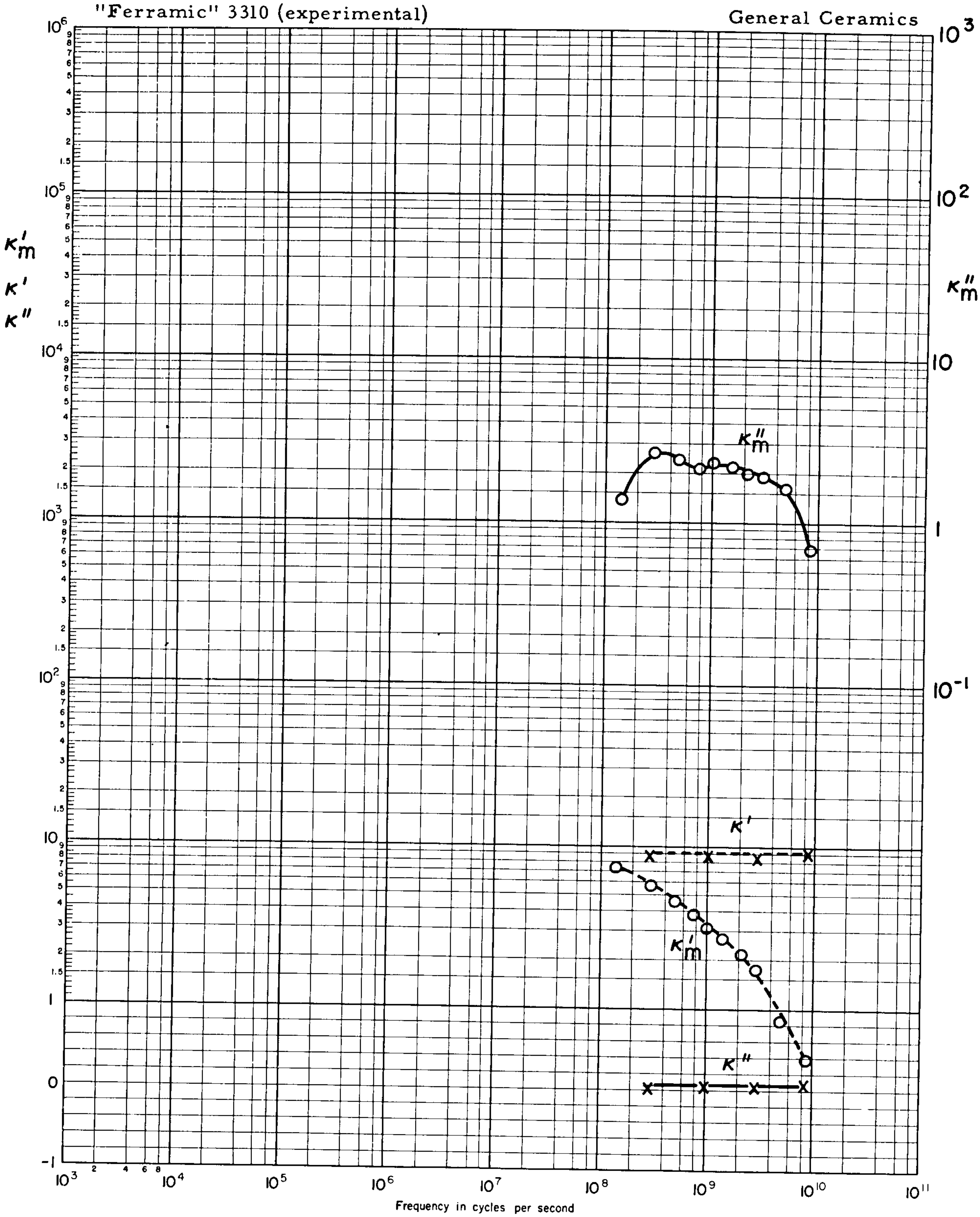
"Ferramic" 1331 General Cerqmivs



IV A 10. Commercial Ferrites

"Ferramic" 3310 (experimental)

General Ceramics

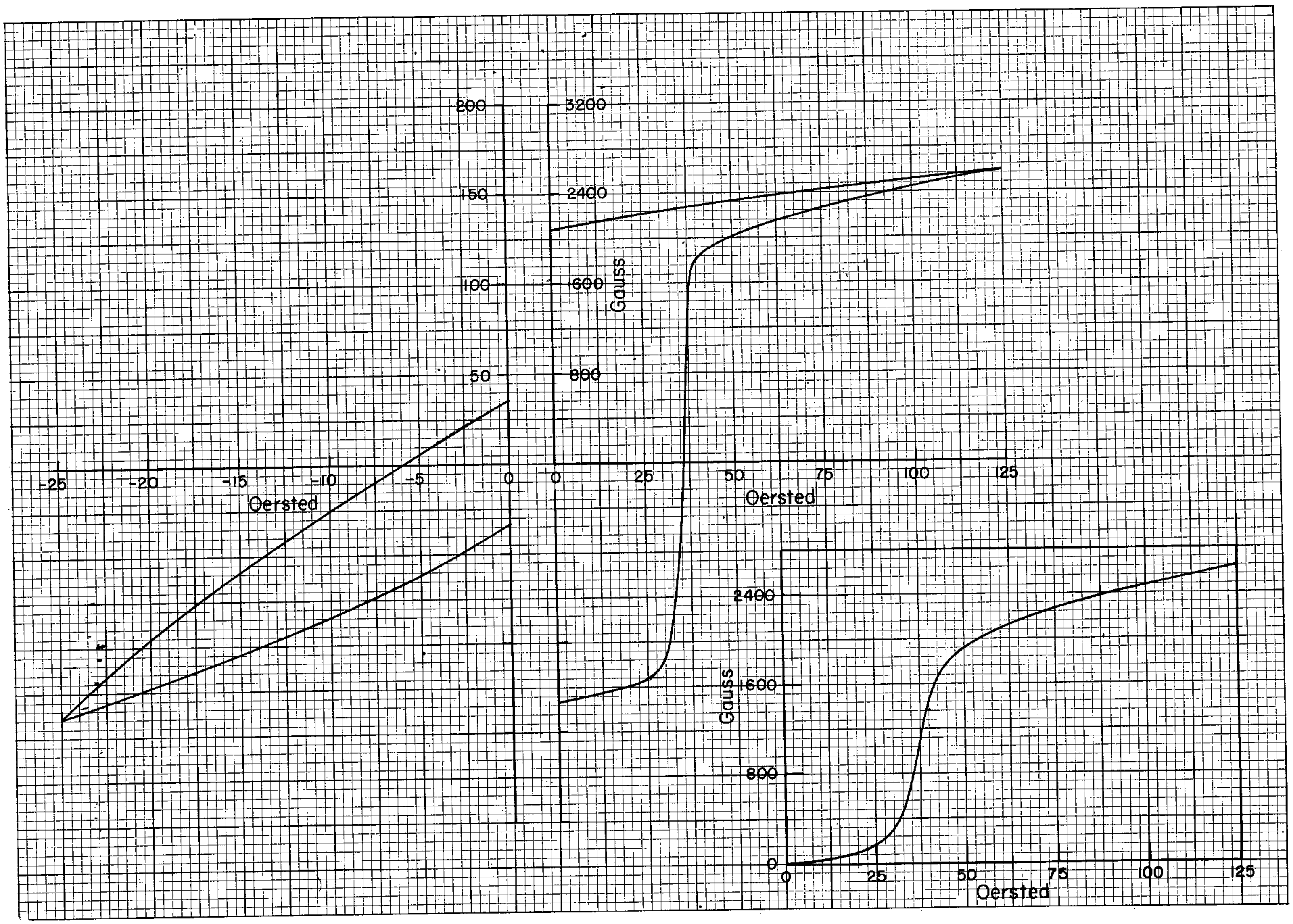


IV B. Hysteresis Loops and Saturation Magnetization

1. Cobalt Ferrite, High Density Ceramic

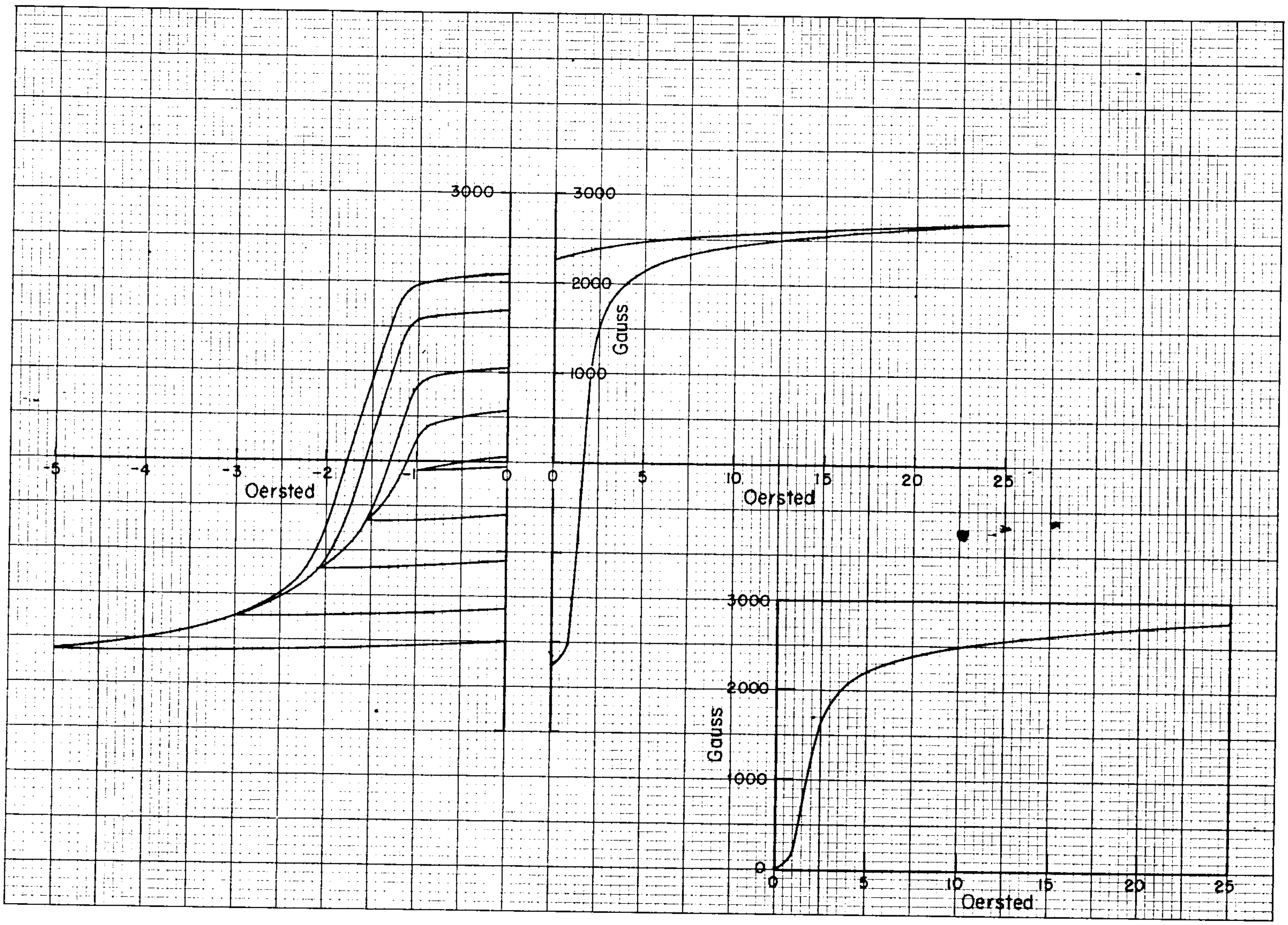
$CoFe_2O_4$ (T = 33°C)

Lab. Ins. Res.



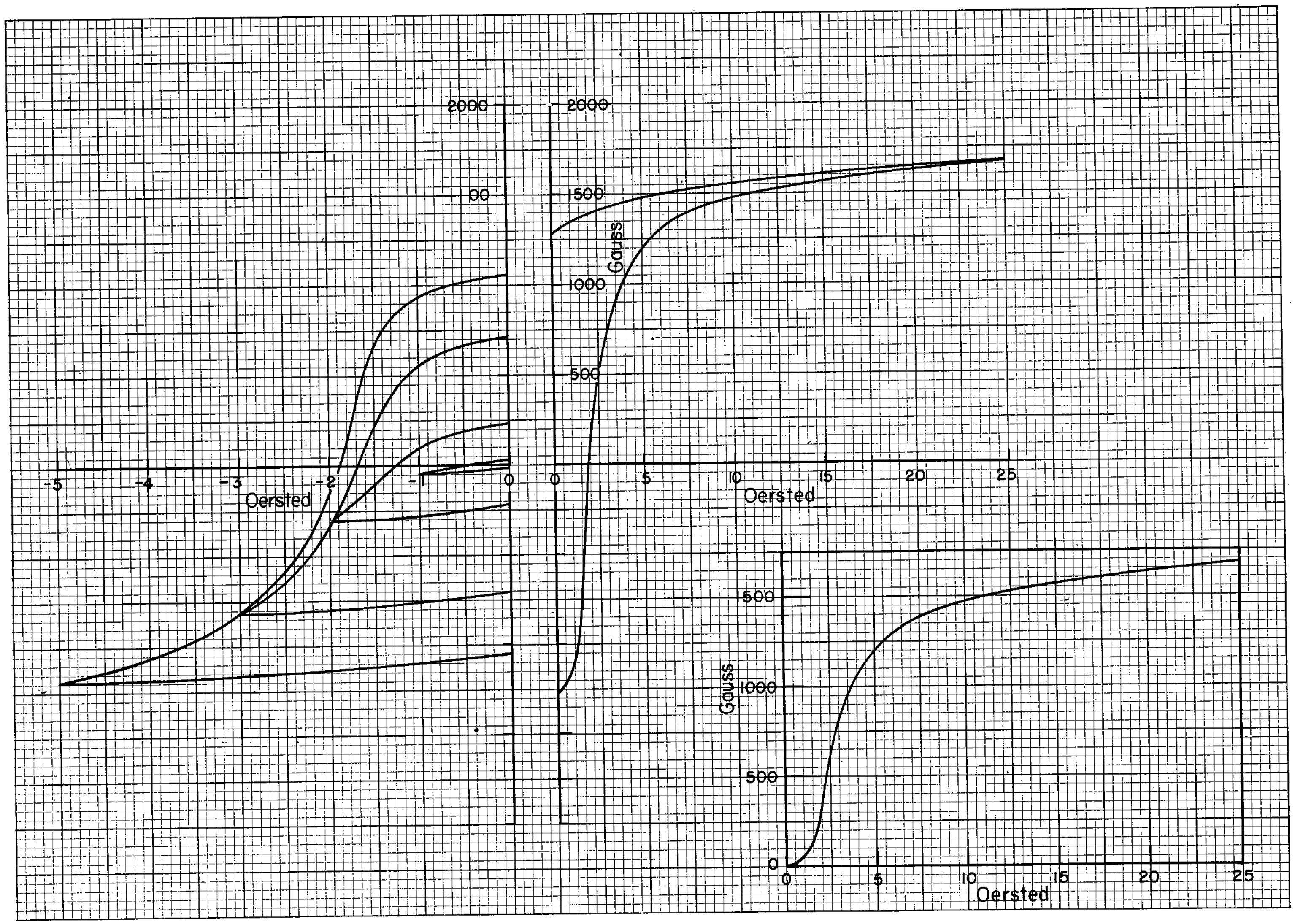
IV B 2. Lithium-Nickel Ferrite Ceramic

$(LiO)_{0.1517}(NiO)_{0.045}(Fe_2O_3)_{0.8035}$ (T = 28°C) M.I.T. Lincoln Lab.



IV B 3. Magnesium Ferrite, High Density Ceramic

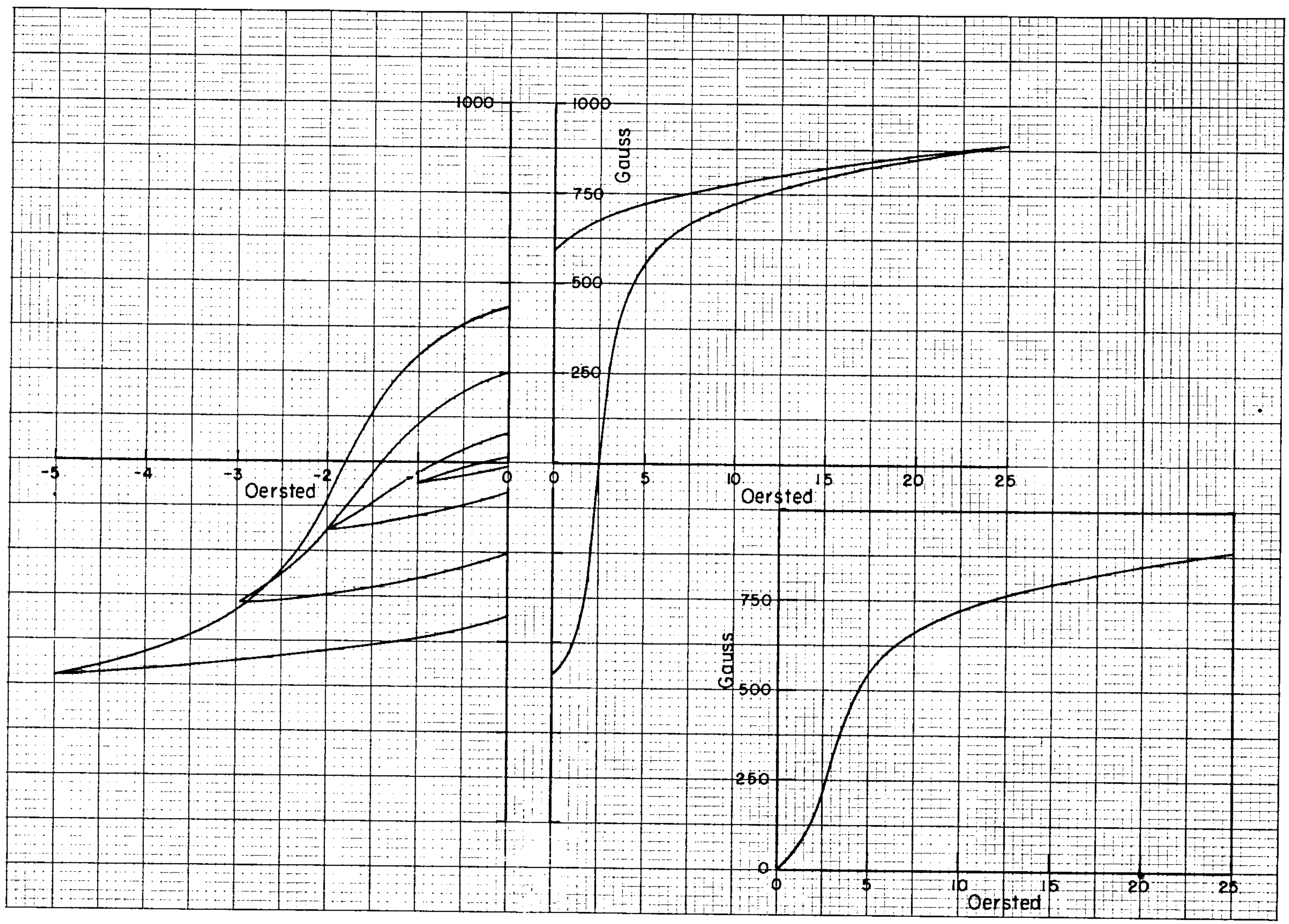
$MgFe_2O_4$ ($T = 29^oC$) Lab. Ins. Res.



IV B 4. Magnesium-Manganese Ferrite Ceramics

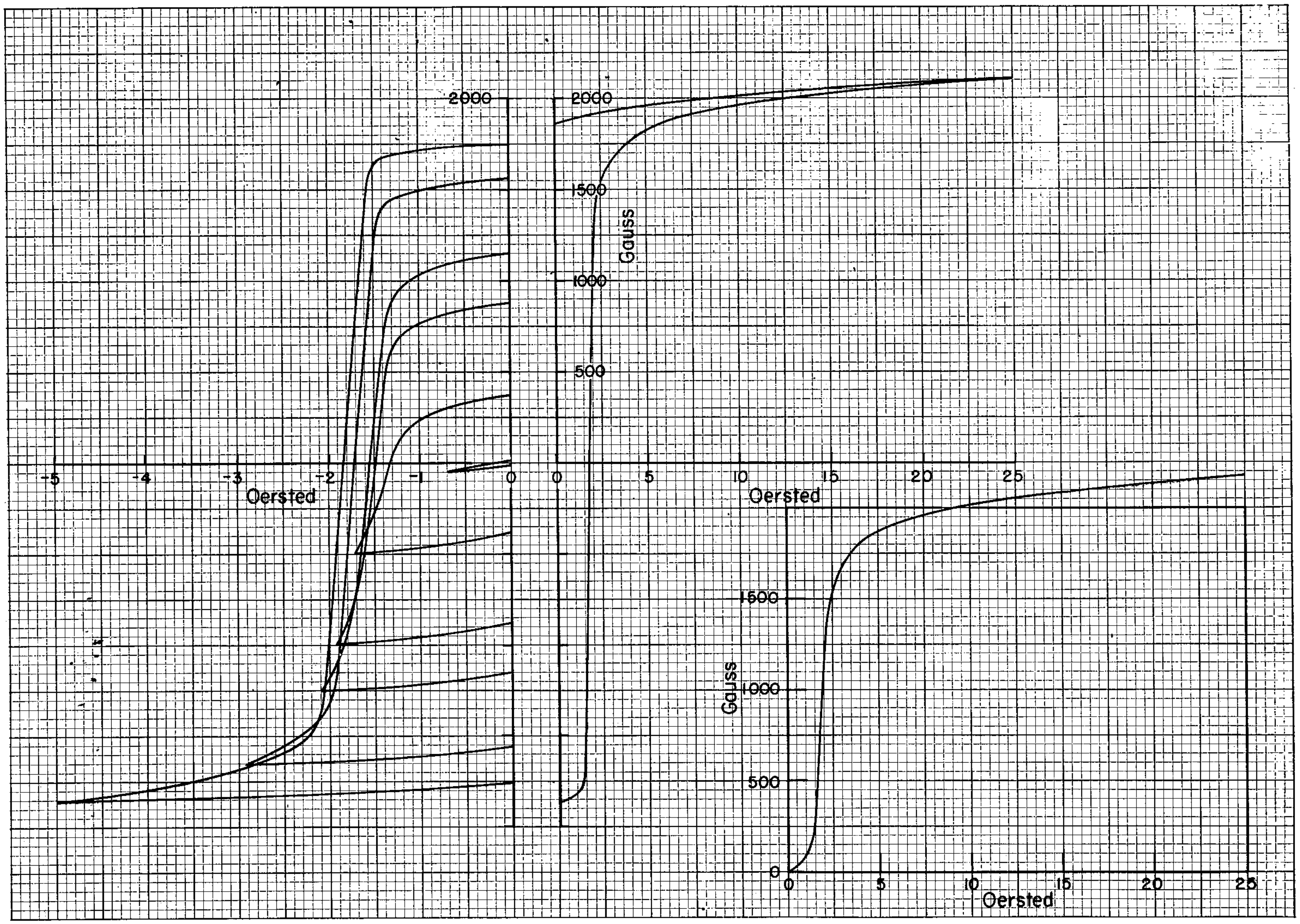
$(MgO)_{0.58}(MnO)_{0.06}(Fe_2O_3)_{0.36}$ (T = 26°C)

Lab. Ins. Res.



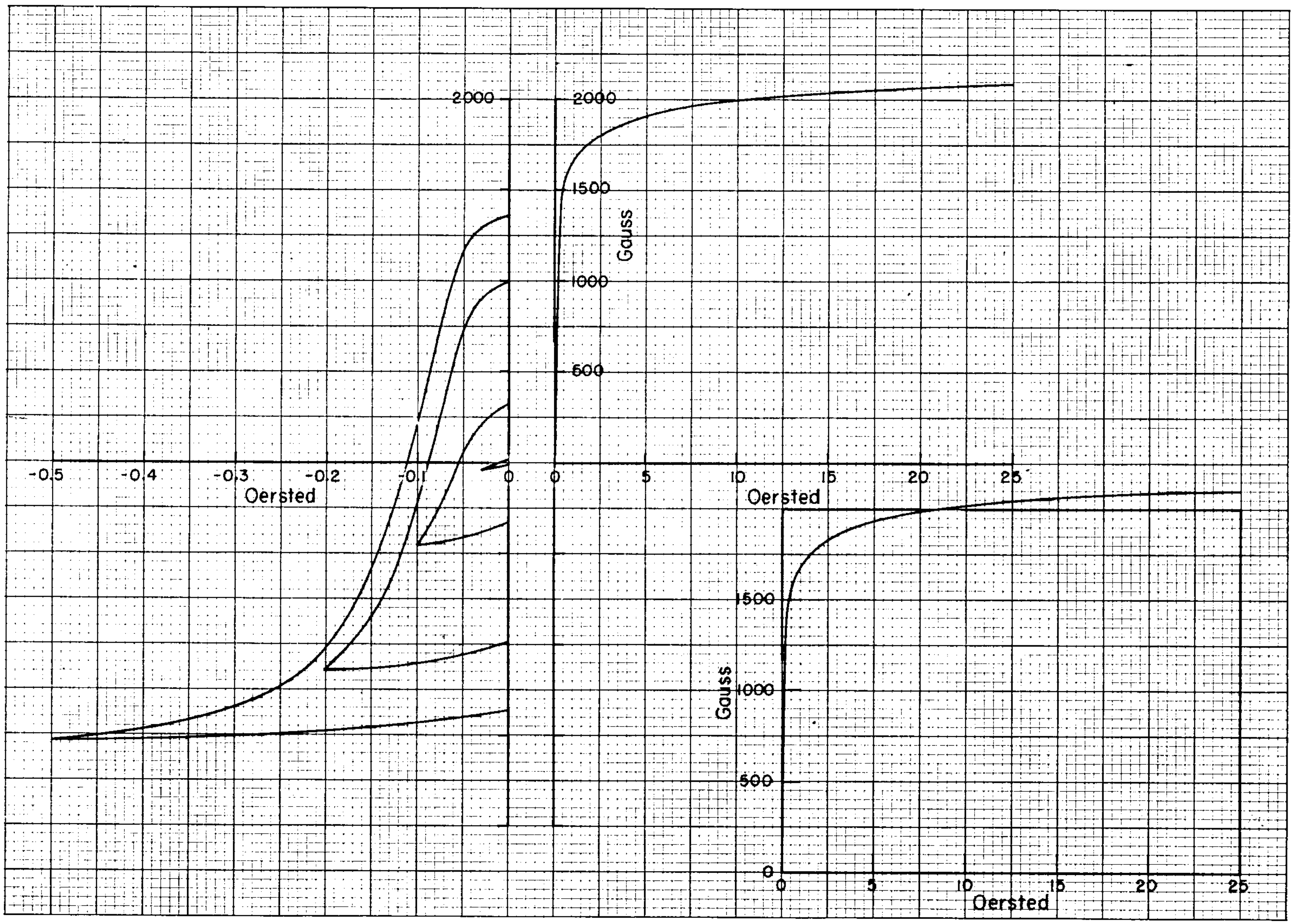
IV B 4. Magnesium-Manganese Ferrite Ceramics

$(MgO)_{0.38}(MnO)_{0.22}(Fe_2O_3)_{0.40}$ (T = 28°C) M.I.T. Lincoln Lab.



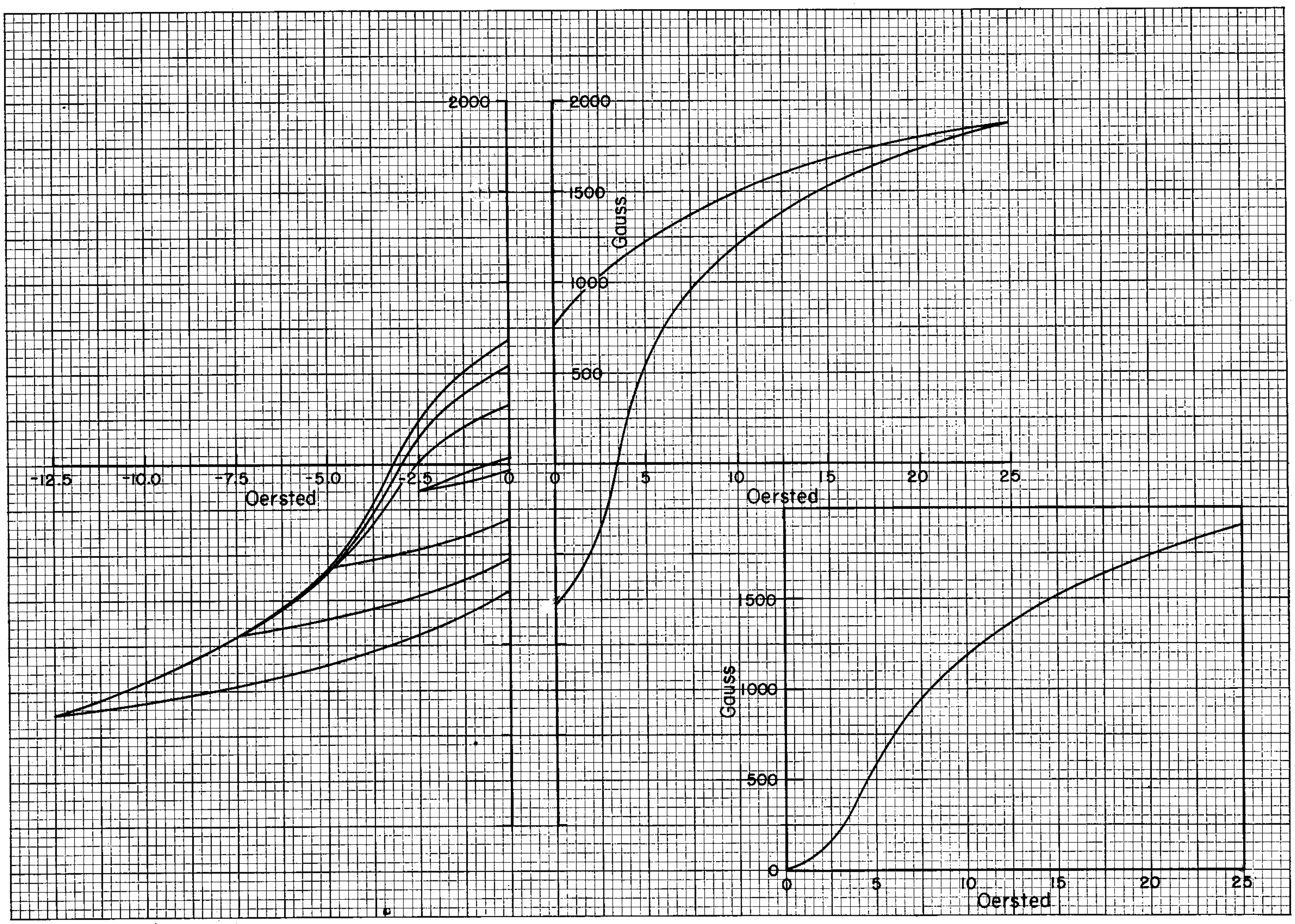
IV B 5. Magnesium-Manganese-Zinc Ferrite Ceramic

$(MgO)_{0.174}(MnO)_{0.209}(ZnO)_{0.221}(Fe_2O_3)_{0.395}$ (T = 28°C) M.I.T. Lincoln Lab.



IV B 6. Nickel Ferrite, High Density Ceramic

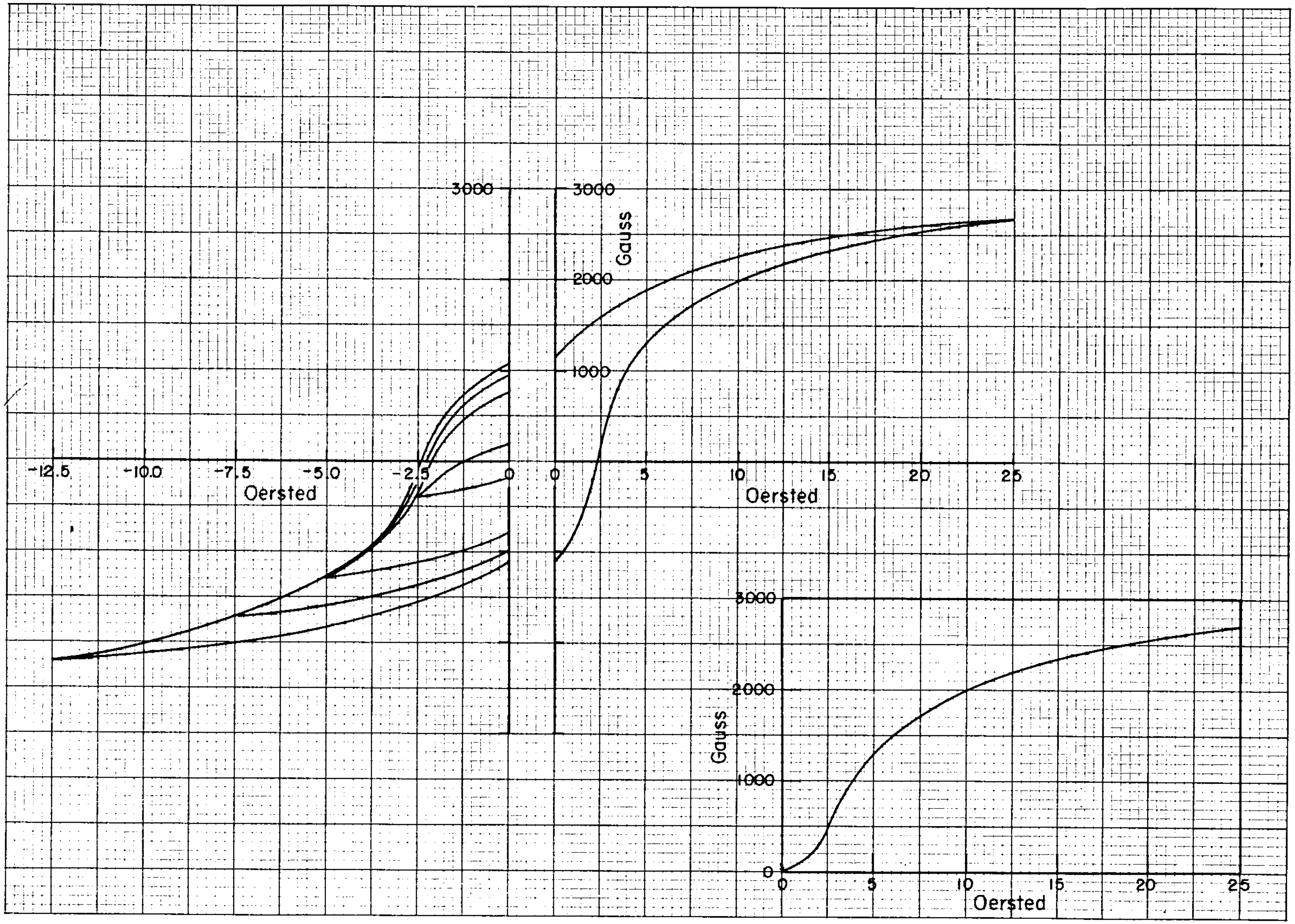
$NiFe_2O_3$ (T = 27°C) Lab. Ins. Res.



IV B 7. Nickel-Zinc **Ferrite**, High Density Ceramics

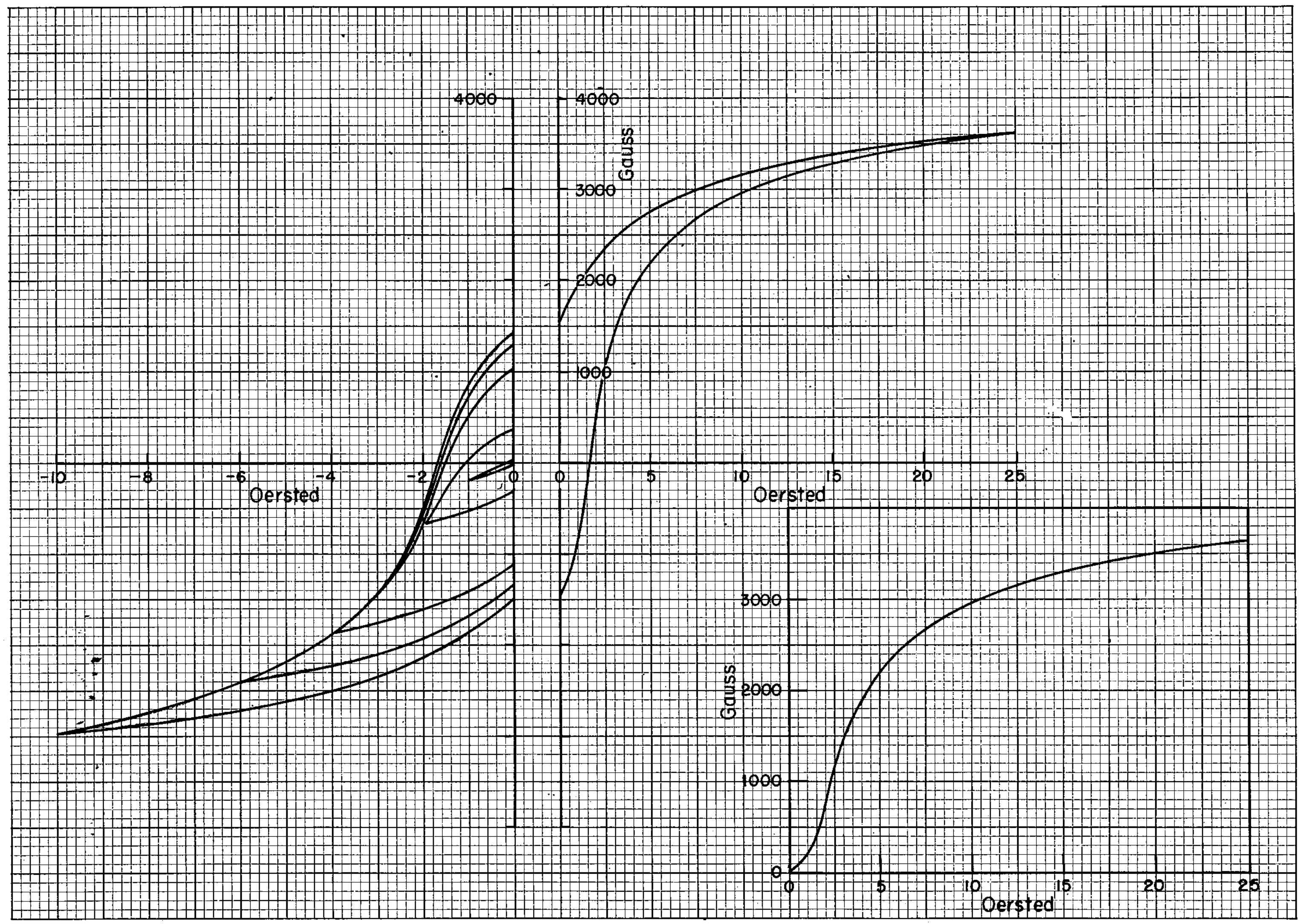
$Ni_{0.9}Zn_{0.1}Fe_2O_4$ (T = 26°C)

Lab. Ins. Res.



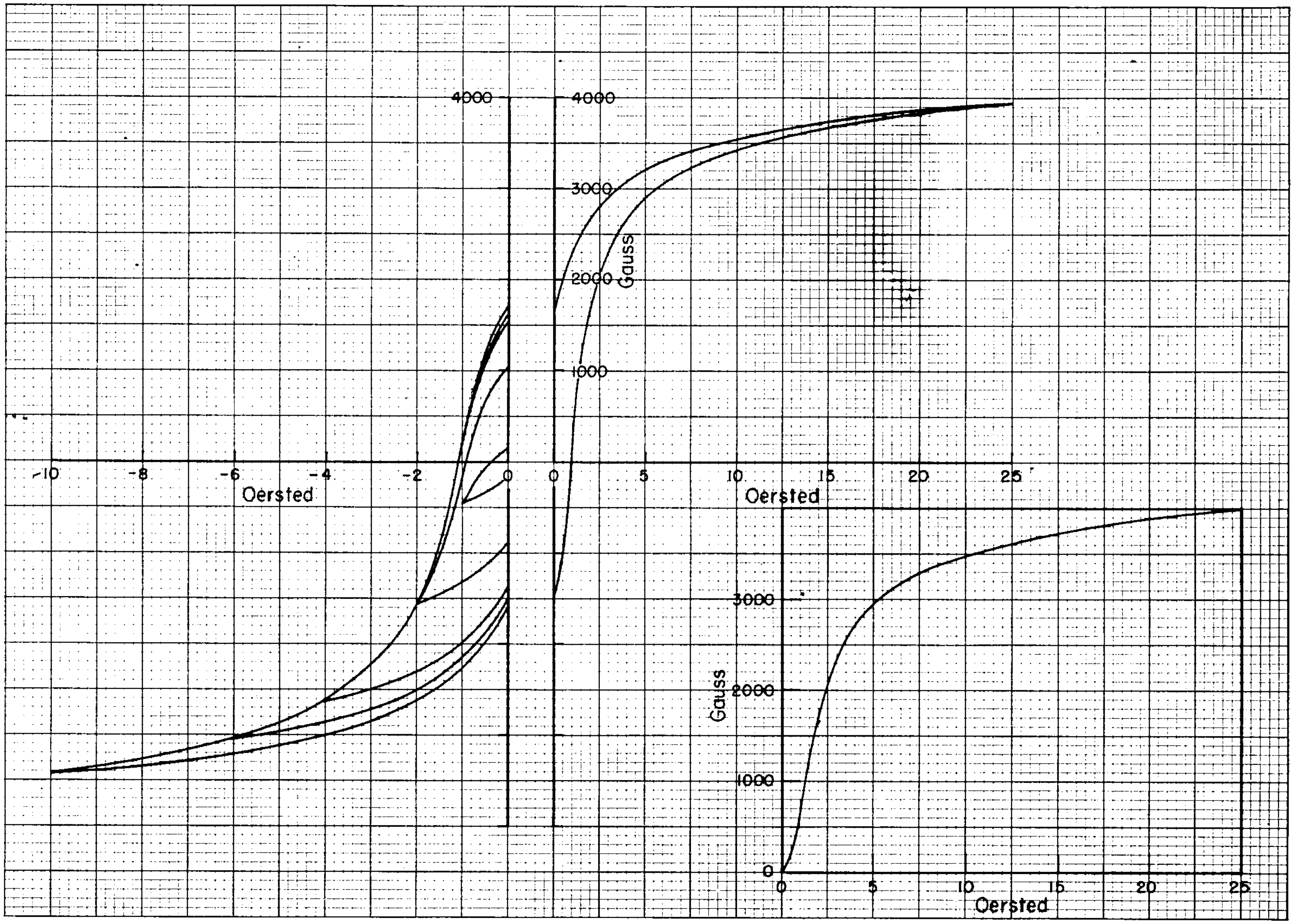
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.8}Zn_{0.2}Fe_2O_4$ (T = 26°C) Lab. Ins. Res.



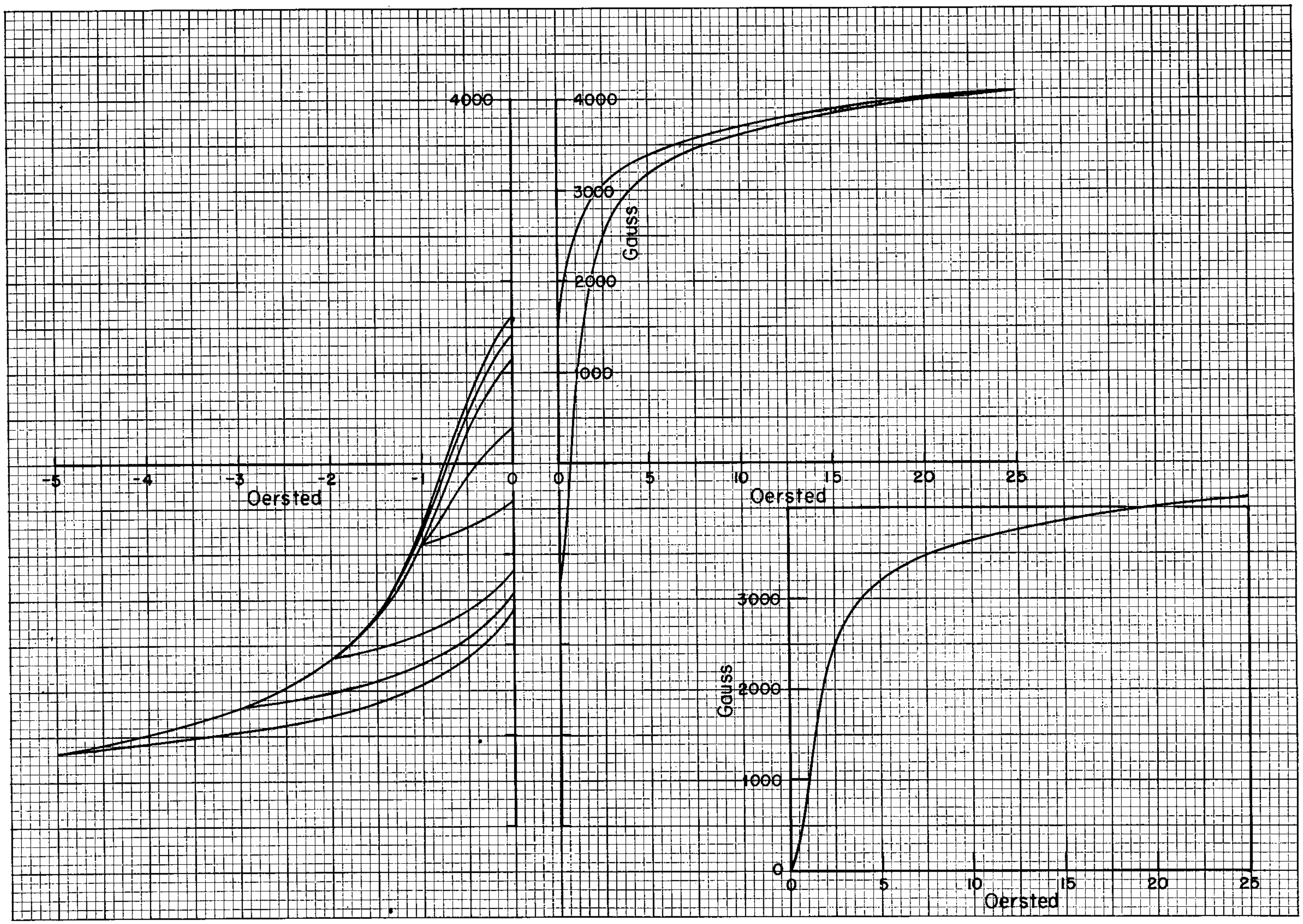
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.7}Zn_{0.3}Fe_2O_4$ (T = 26°C) Lab. Ins. Res.



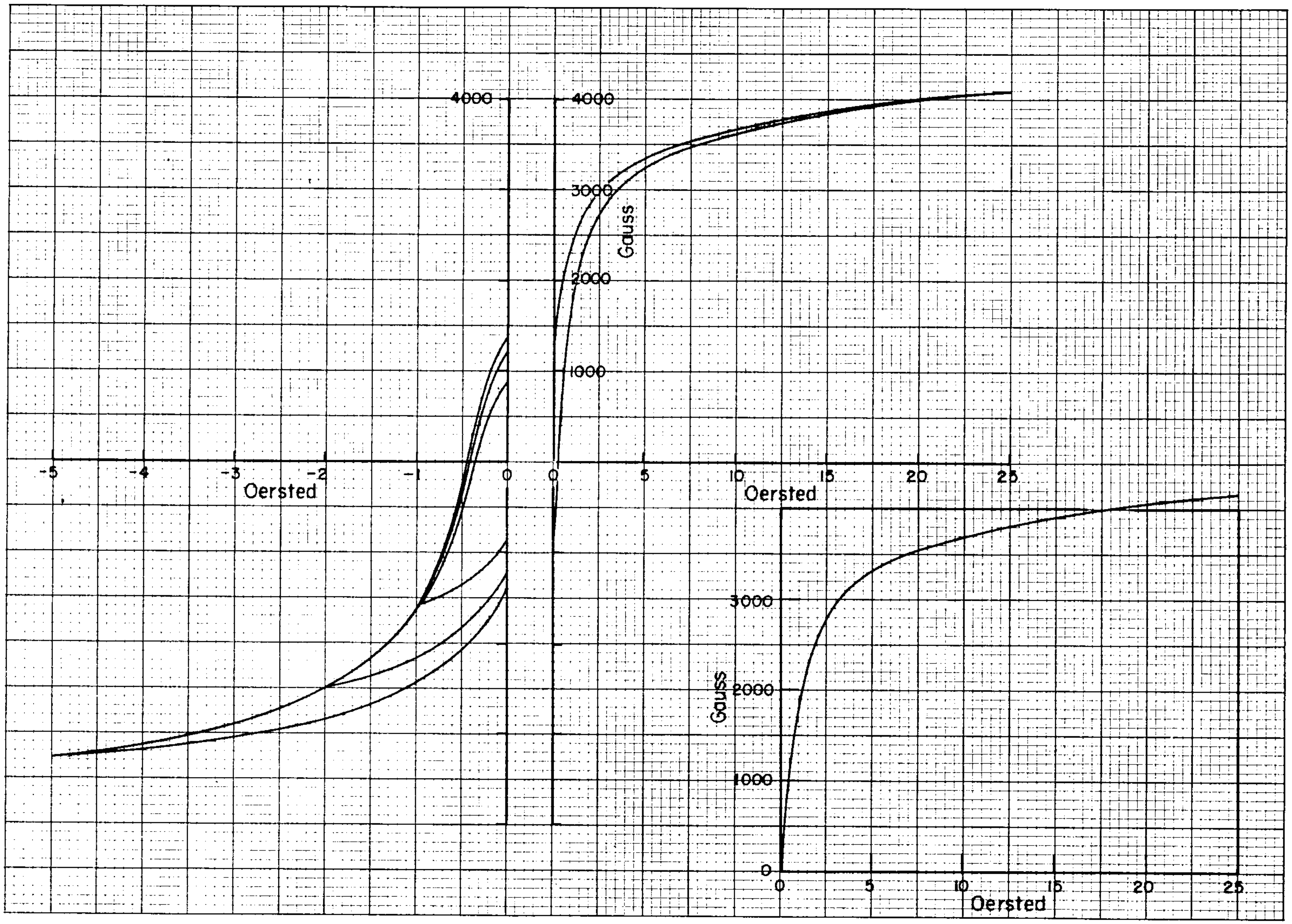
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.6}Zn_{0.4}Fe_2O_4$ (T = 26°C) Lab. Ins. Res.



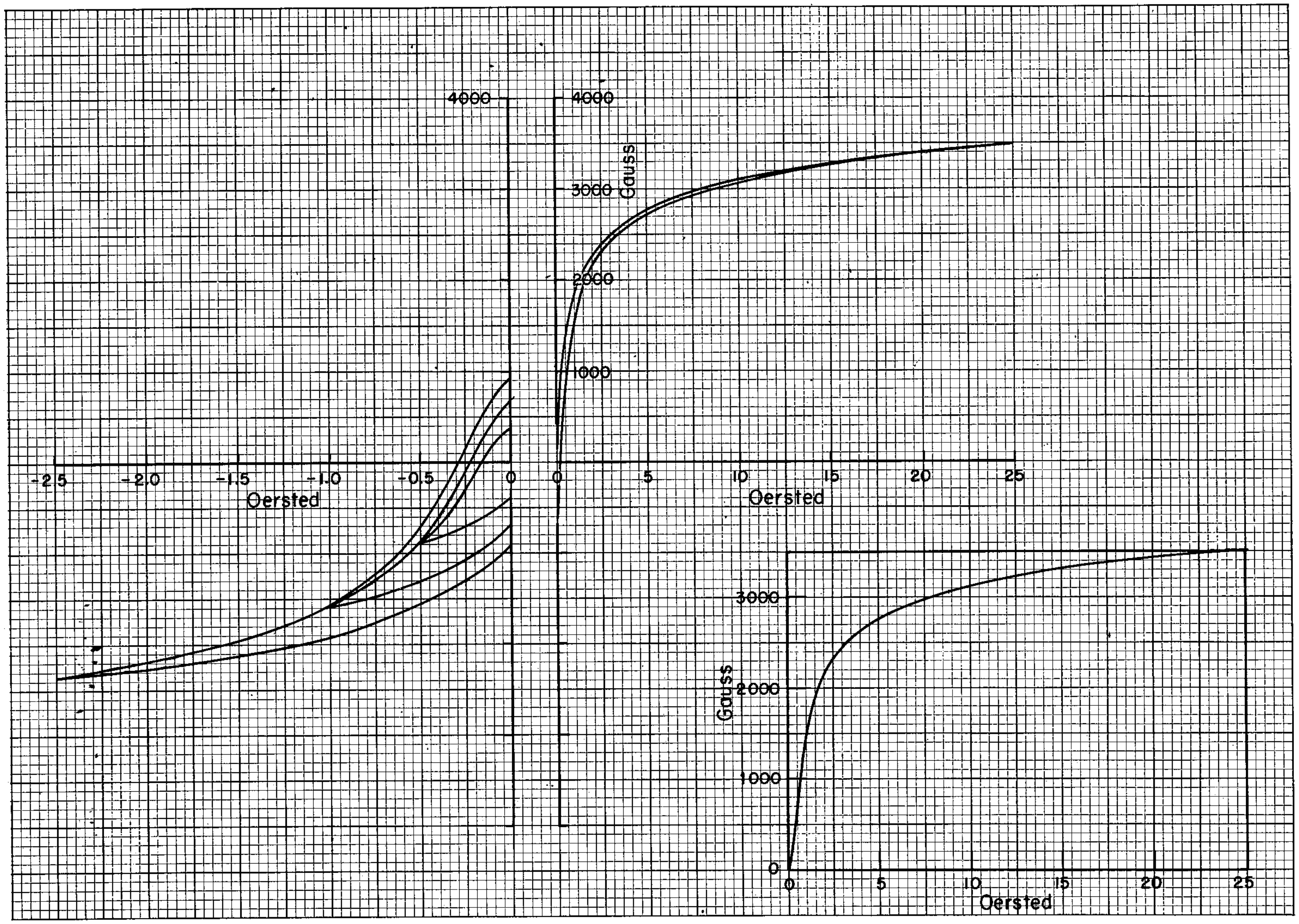
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.5}Zn_{0.5}Fe_2O_4$ (T = 26°C) Lab. Ins. Res.



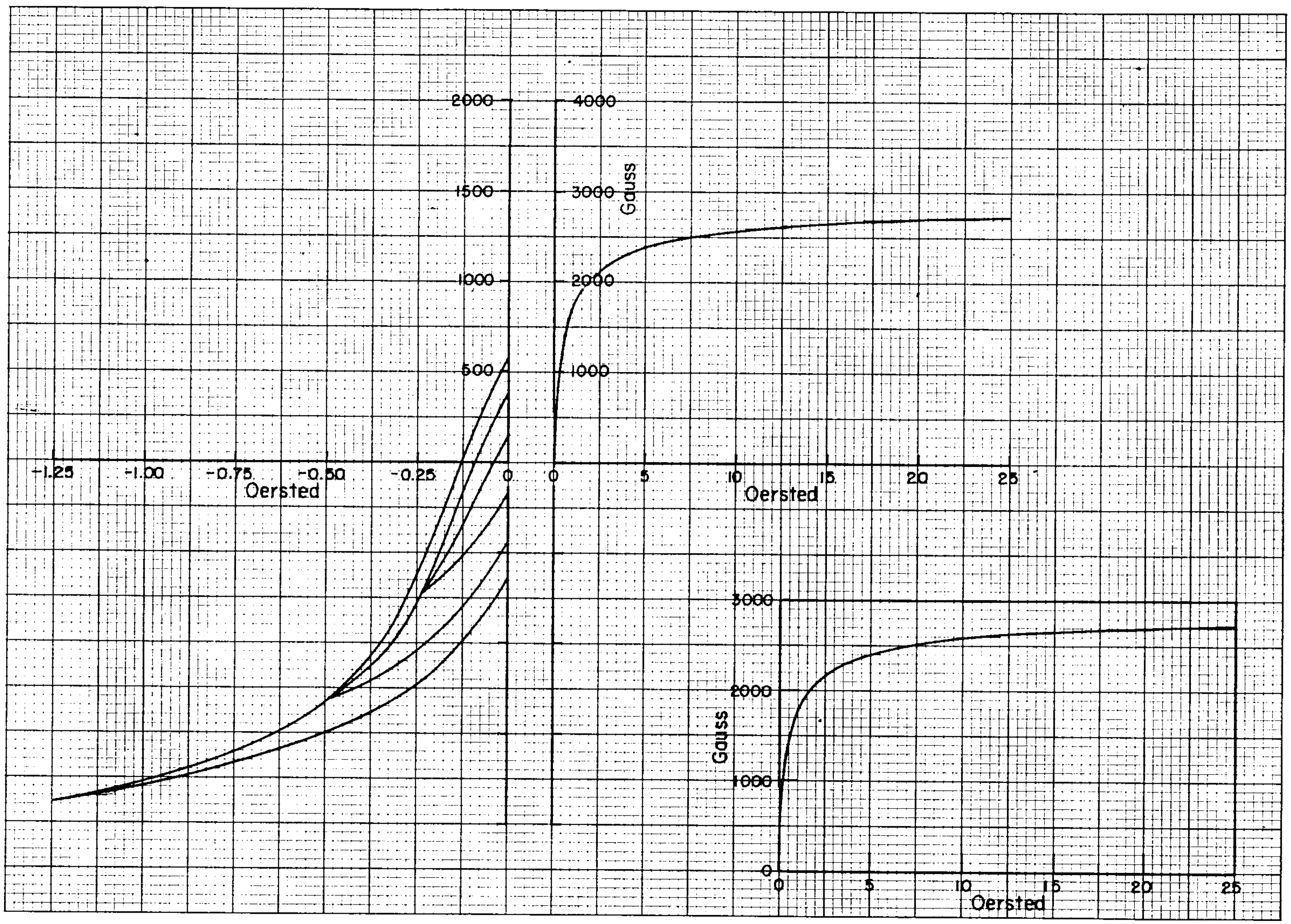
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.4}Zn_{0.6}Fe_2O_4$ (T = 26°C) Lab. Ins. Res.



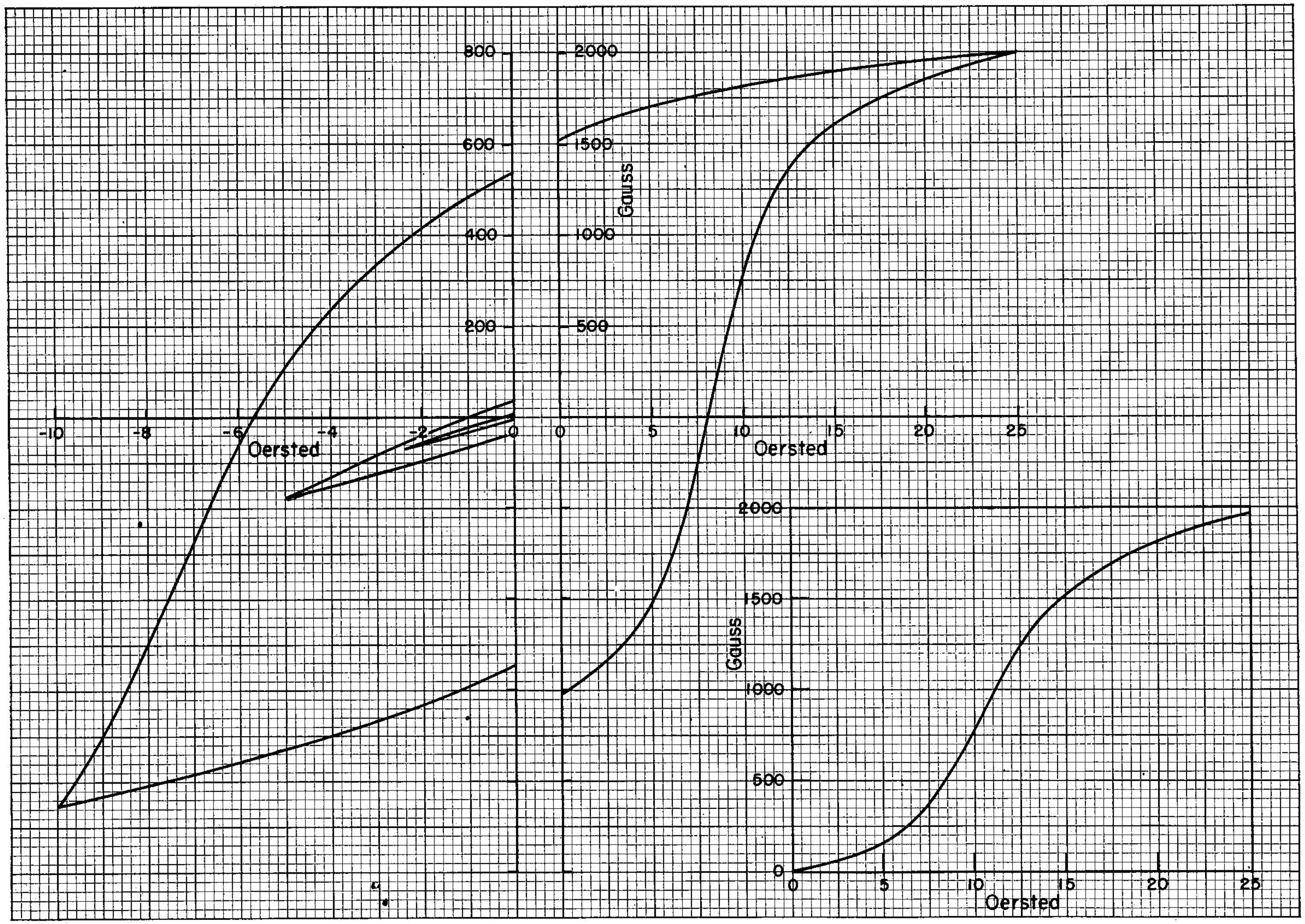
IV B 7. Nickel-Zinc Ferrite, High Density Ceramics

$Ni_{0.3}Zn_{0.7}Fe_2O_4$ (T = 29°C) Lab. Ins. Res.



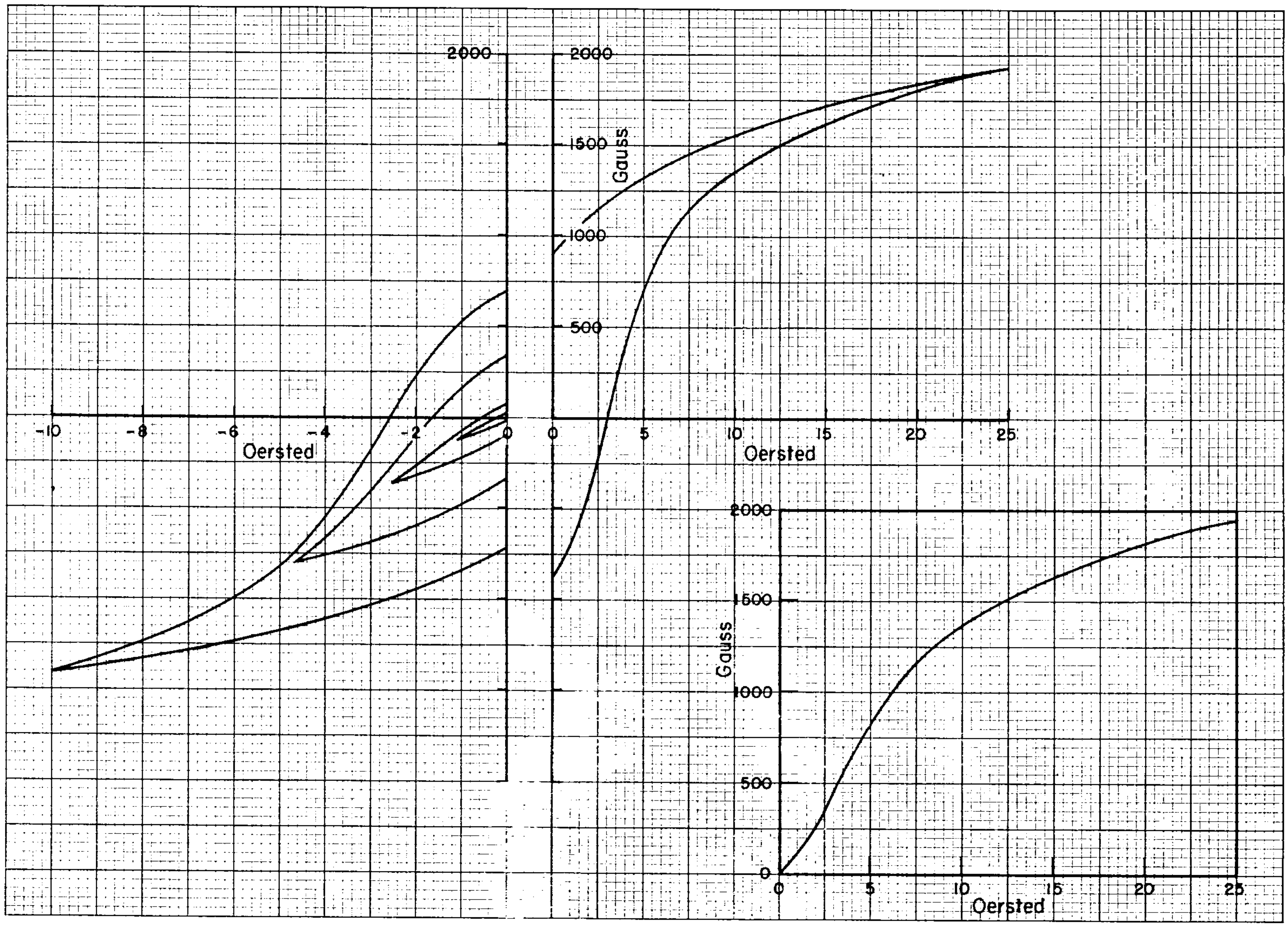
IV B 8. Commercial Ferrite Ceramics

"Ferramic" A (T = 29°C) General Ceramics



IV B 8. Commercial Ferrite Ceramics

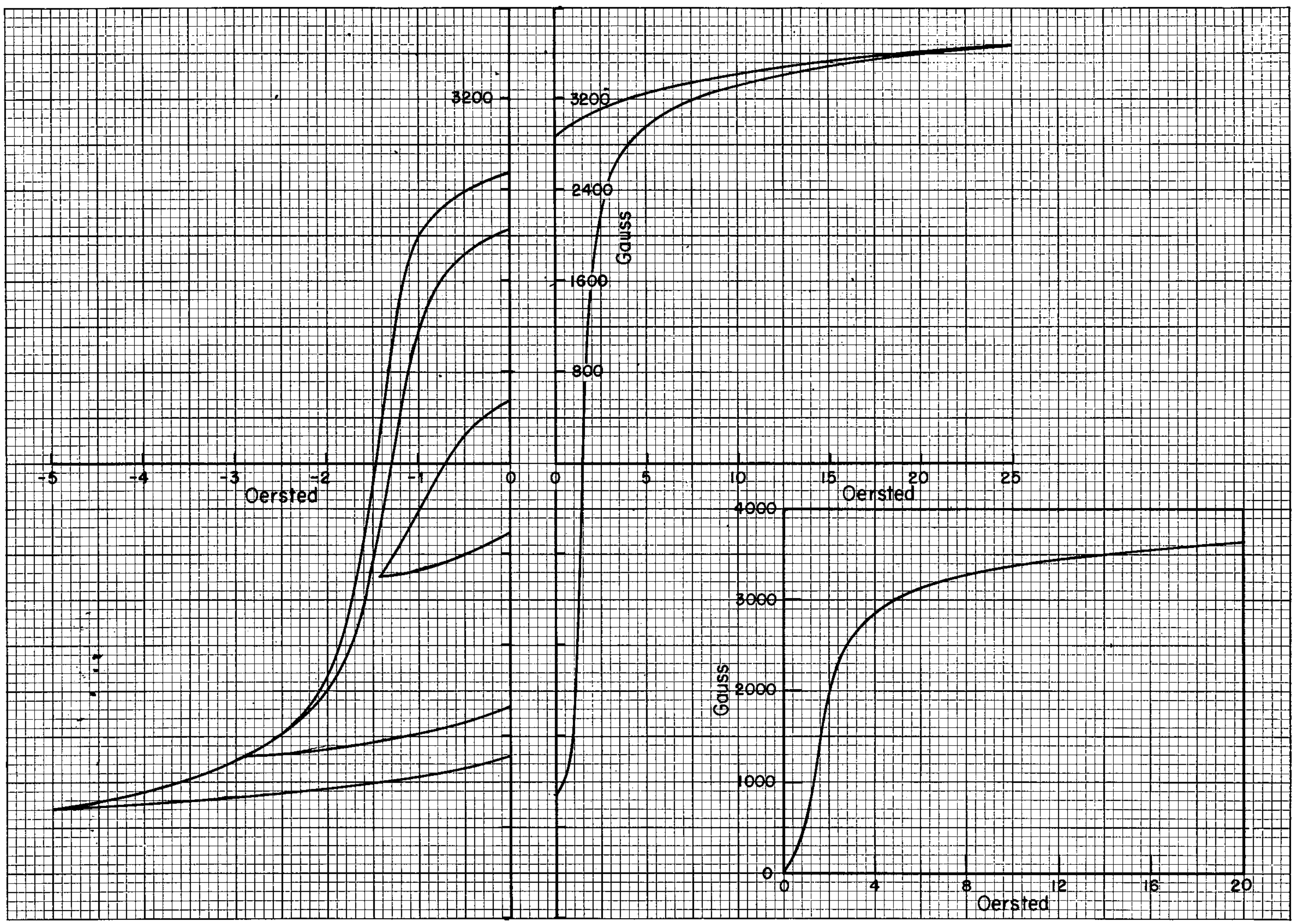
"Ferramic" B ($T = 25^{o}C$) General Ceramics



IV B 8. Commercial Ferrite Ceramics

"Ferramic" C

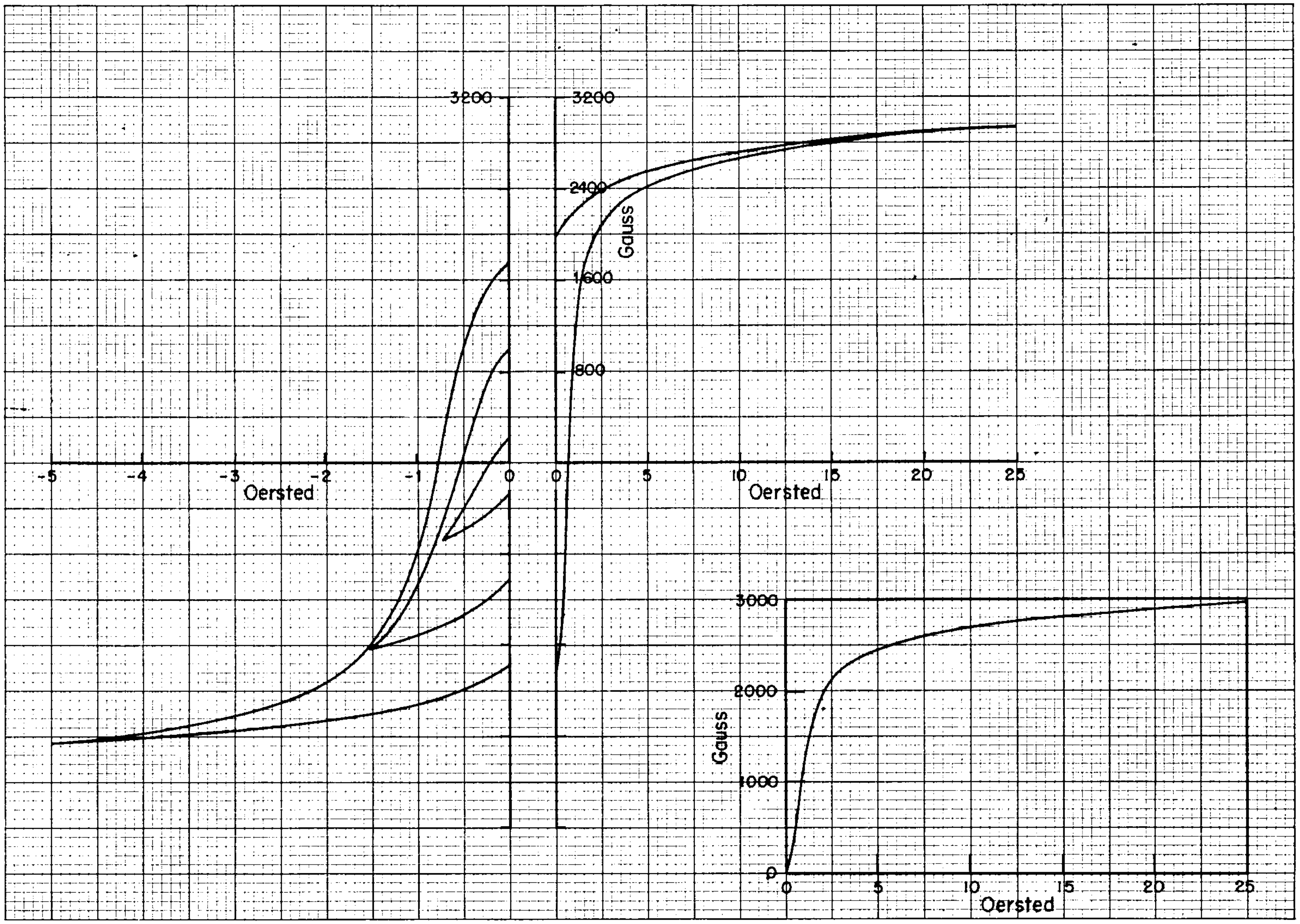
General Ceramics



IV B 8. Commercial Ferrite Ceramics

"Ferramic" D

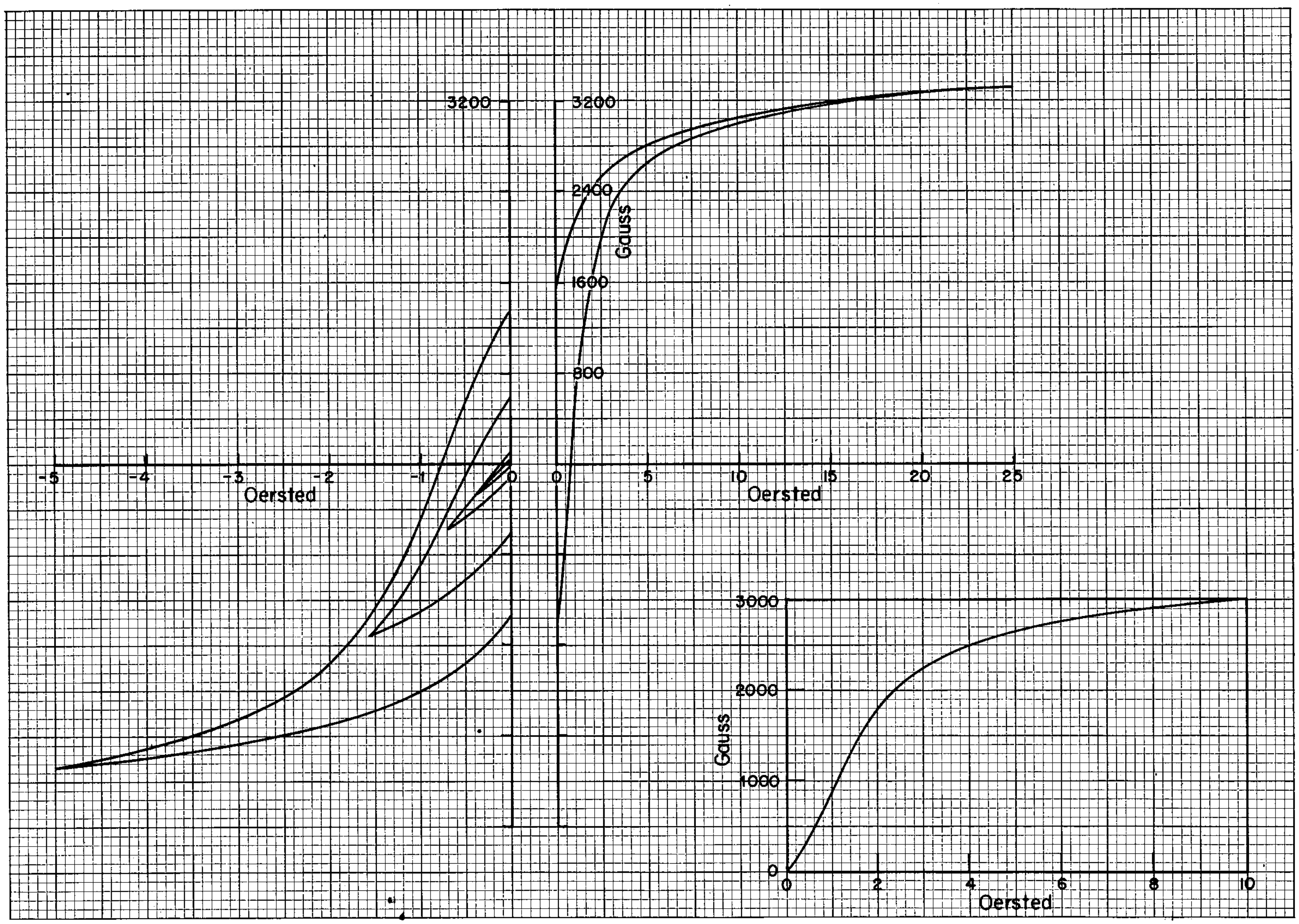
General Ceramics



IV B 8. Commercial Ferrite Ceramics

"Ferramic" E (T = 24°C)

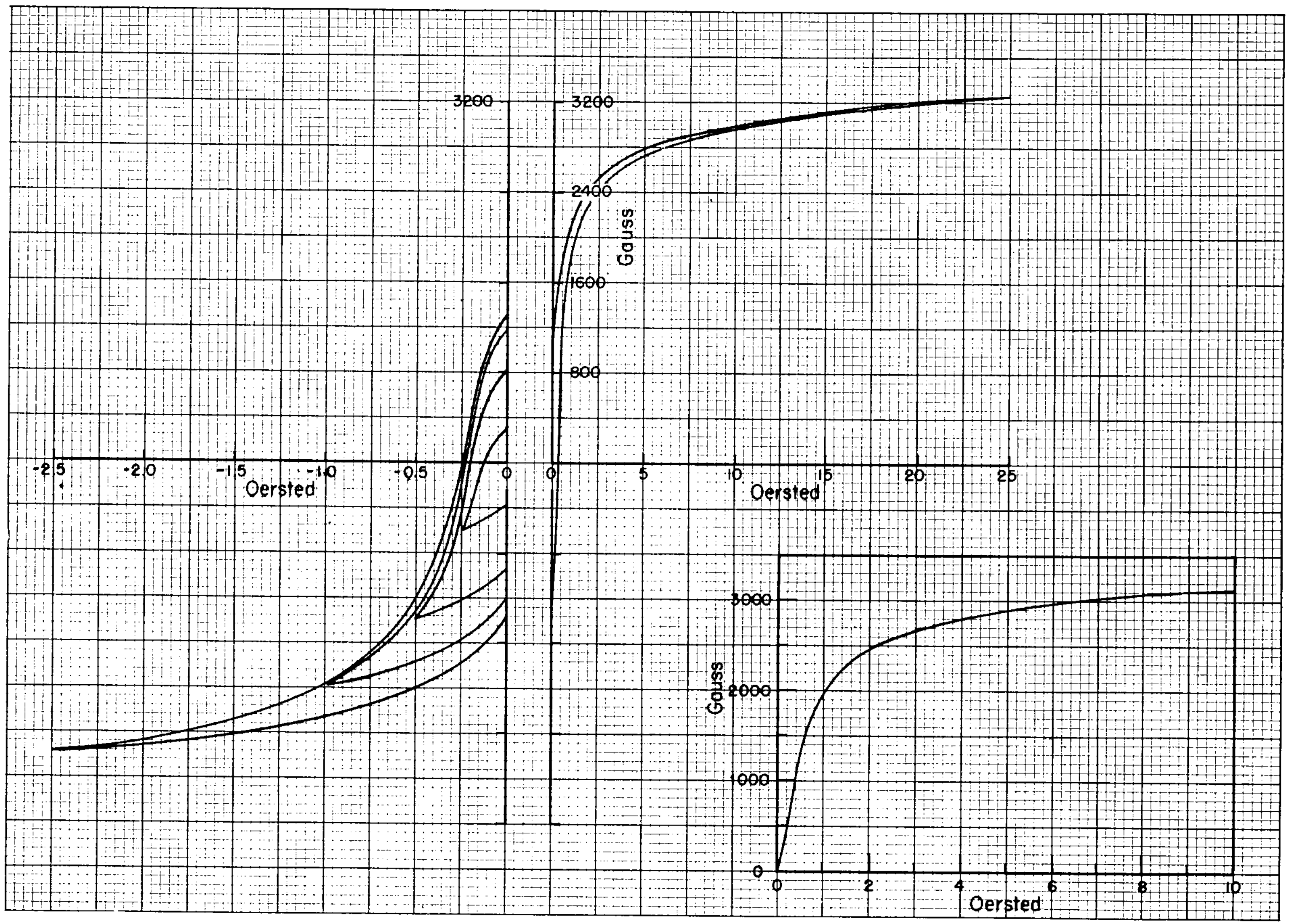
General Ceramics



IV B 8. Commercial Ferrite Ceramics

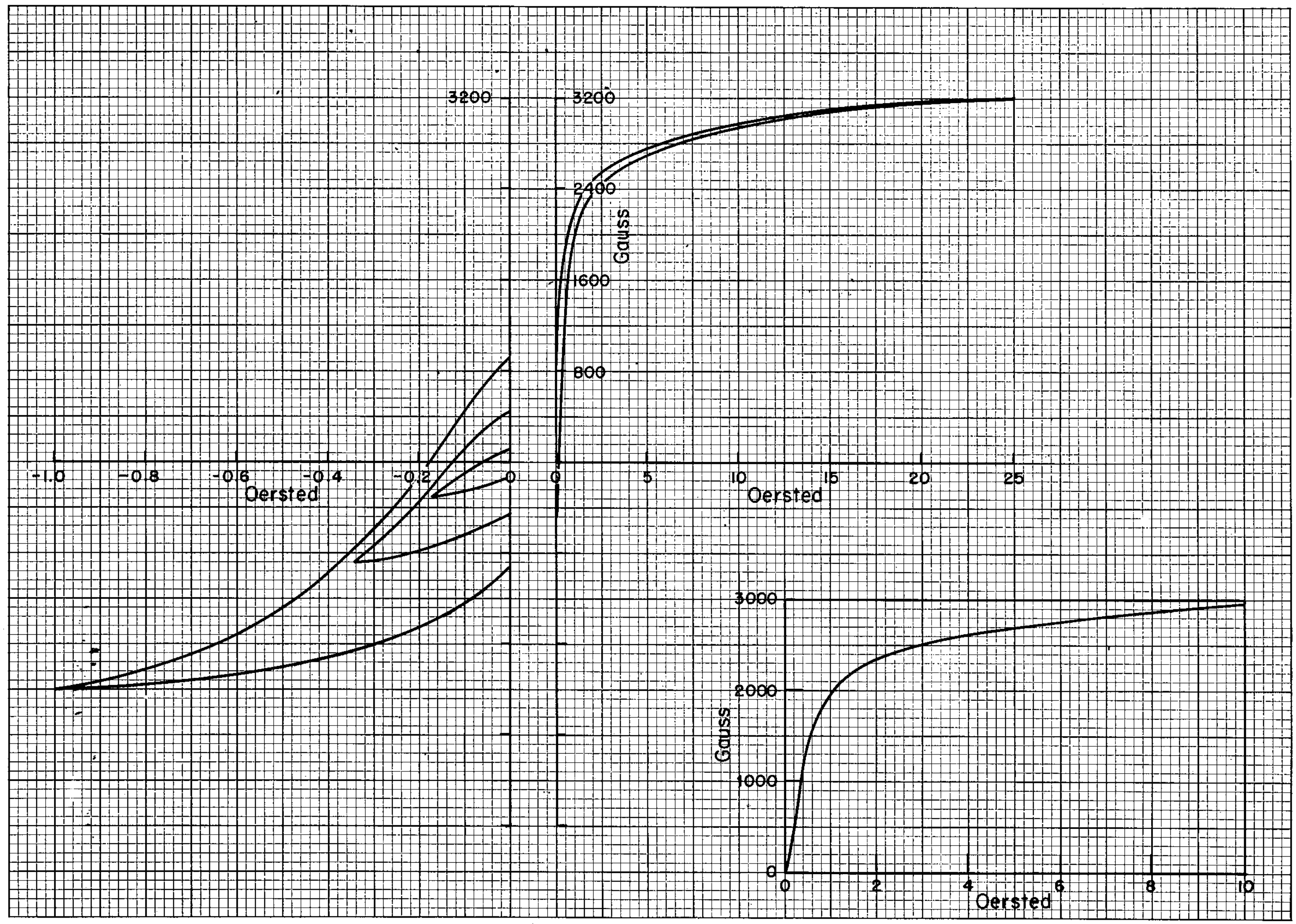
"Ferramic" G (T = 25°C)

General Ceramics



IV B 8. Commercial Ferrite Ceramics

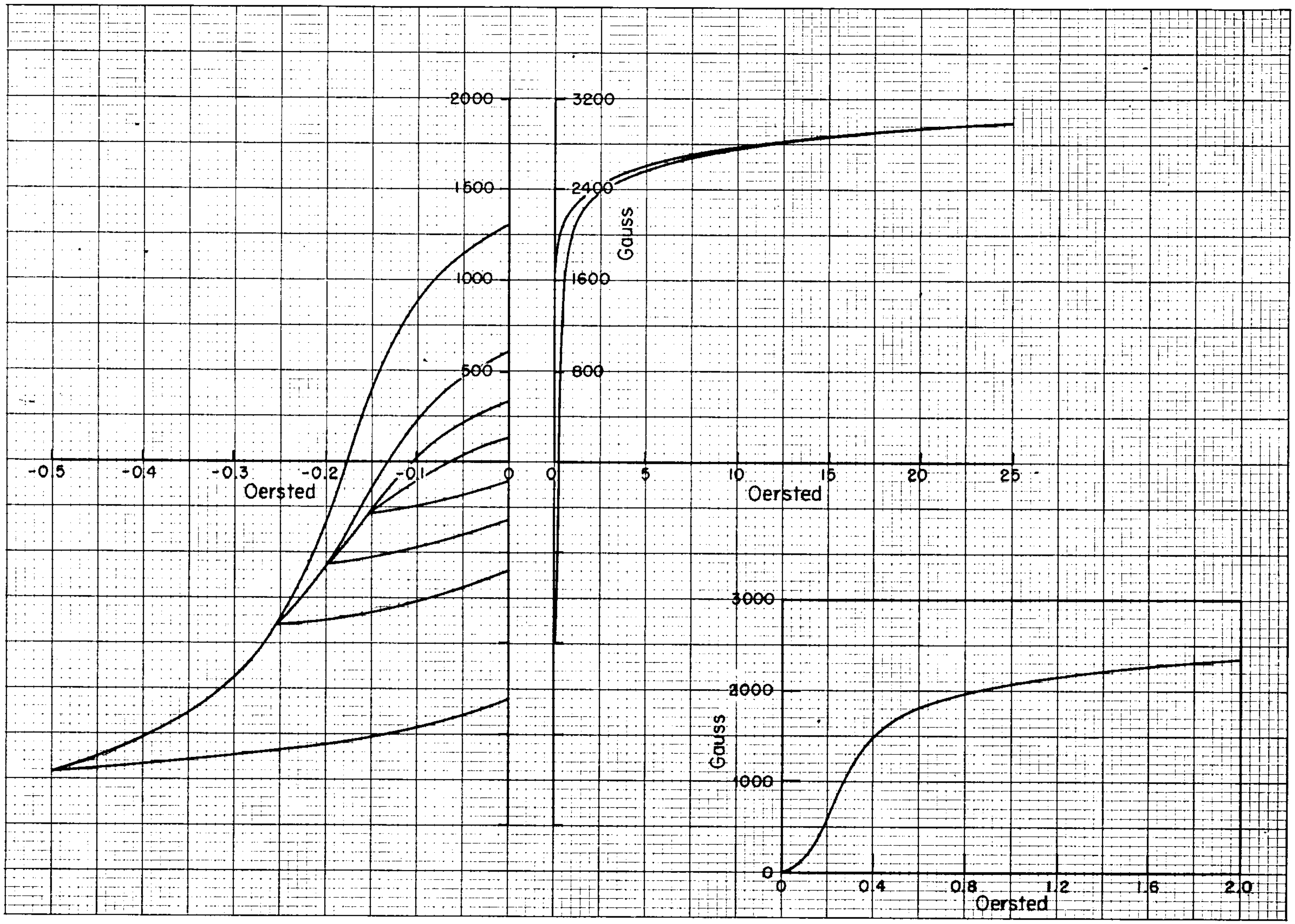
"Ferramic" H (T = 26.5°C) General Ceramics



IV B 8. Commercial **F**errite Ceramics

"**F**erramic" H-1 (T = 27^{o}C)

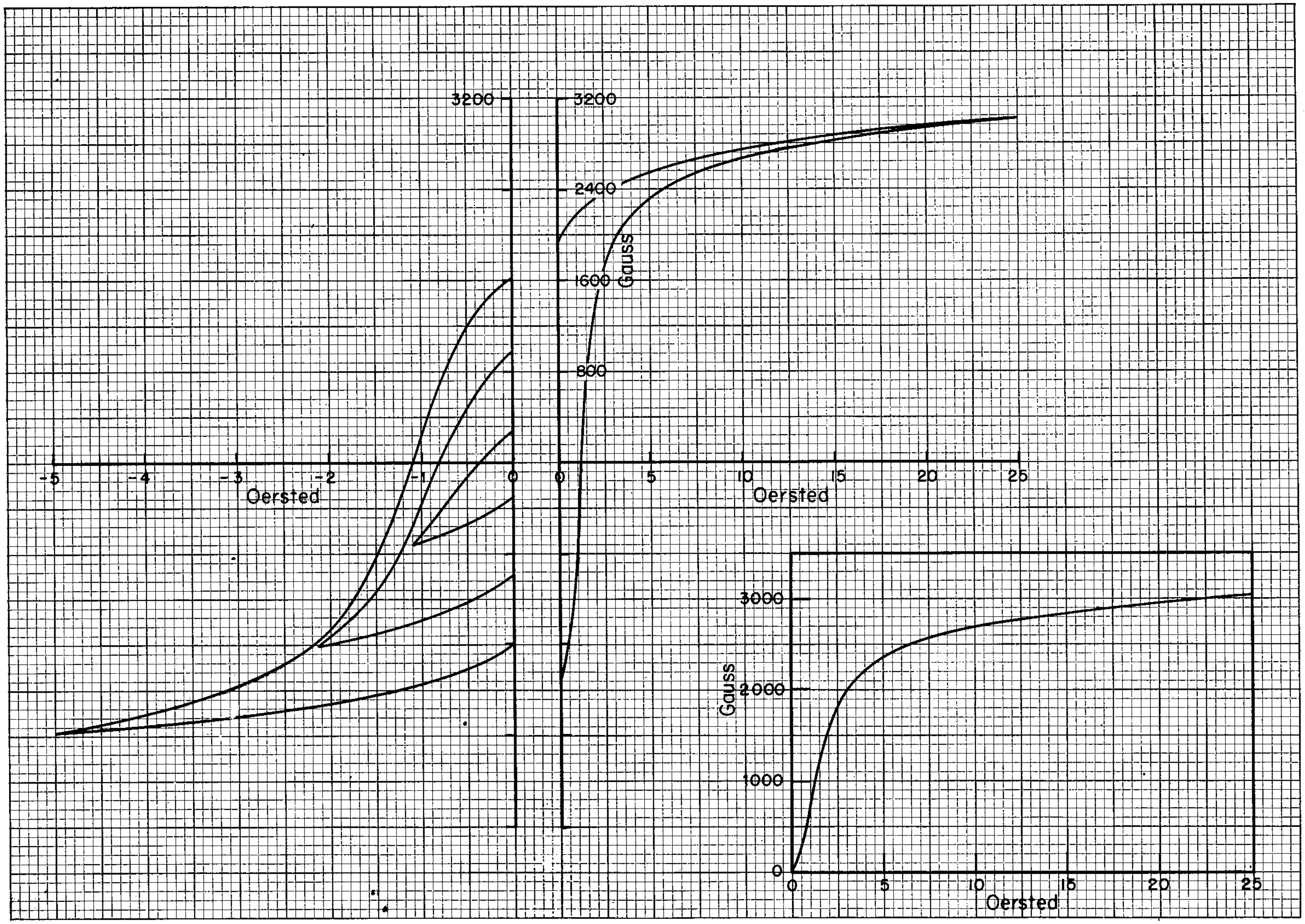
General Ceramics



IV B 8. Commercial Ferrite Ceramics

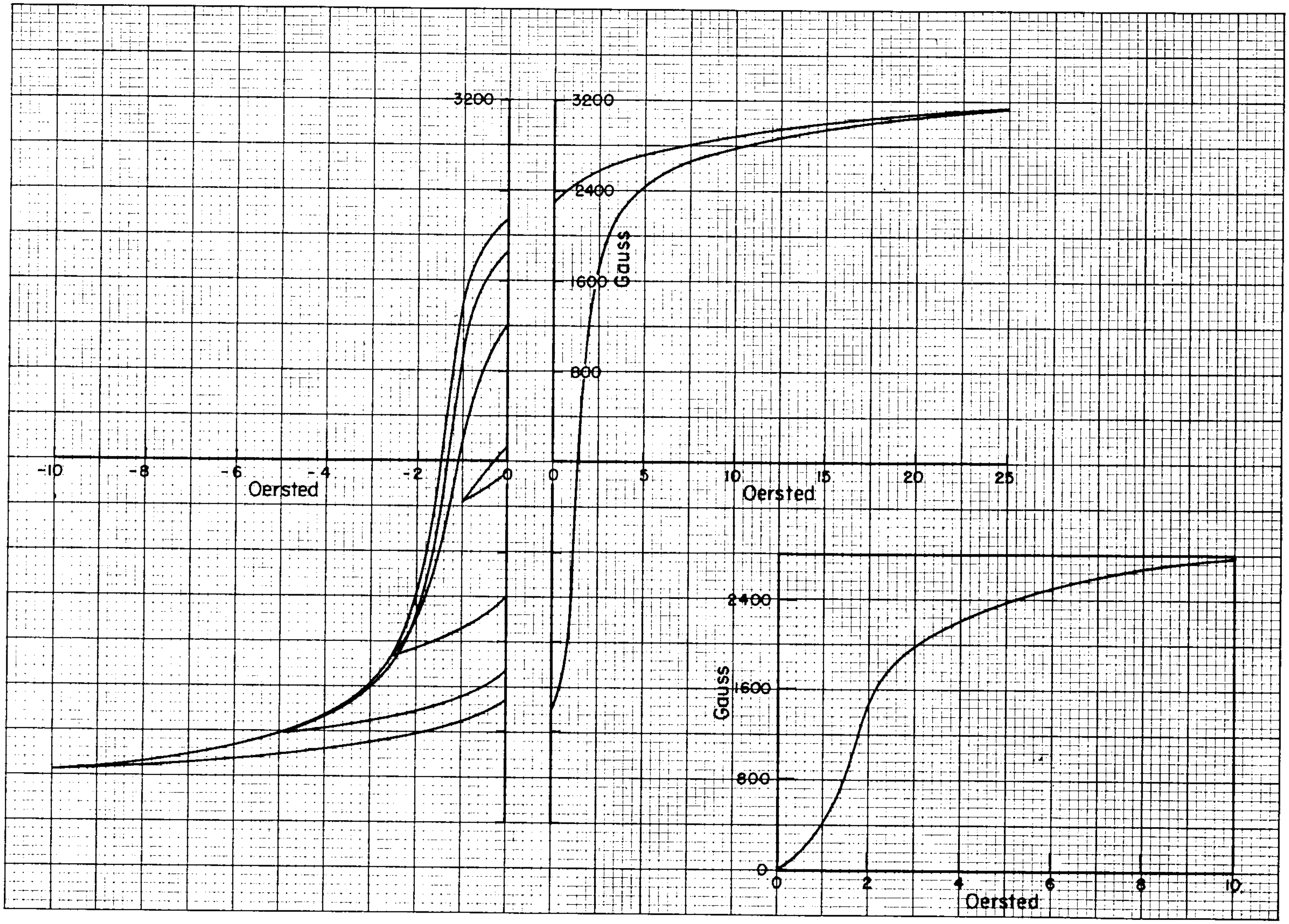
"Ferramic" $\widetilde{J}$ (T = 25°C)

General Ceramics



IV B 8. Commercial Ferrite Ceramics

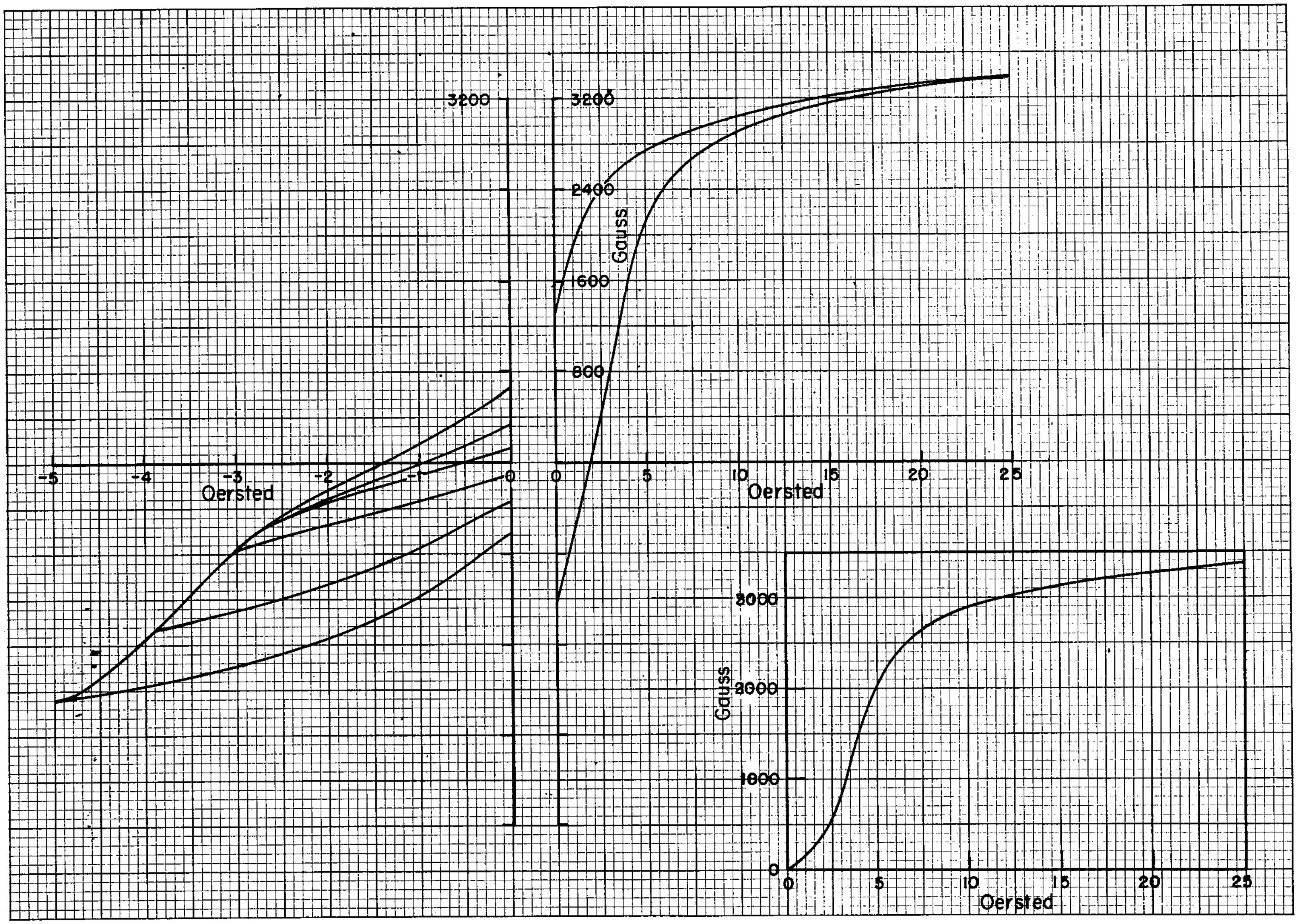
"Ferramic" N (T = 27°C) General Ceramics



IV B 8. Commercial Ferrite Ceramics

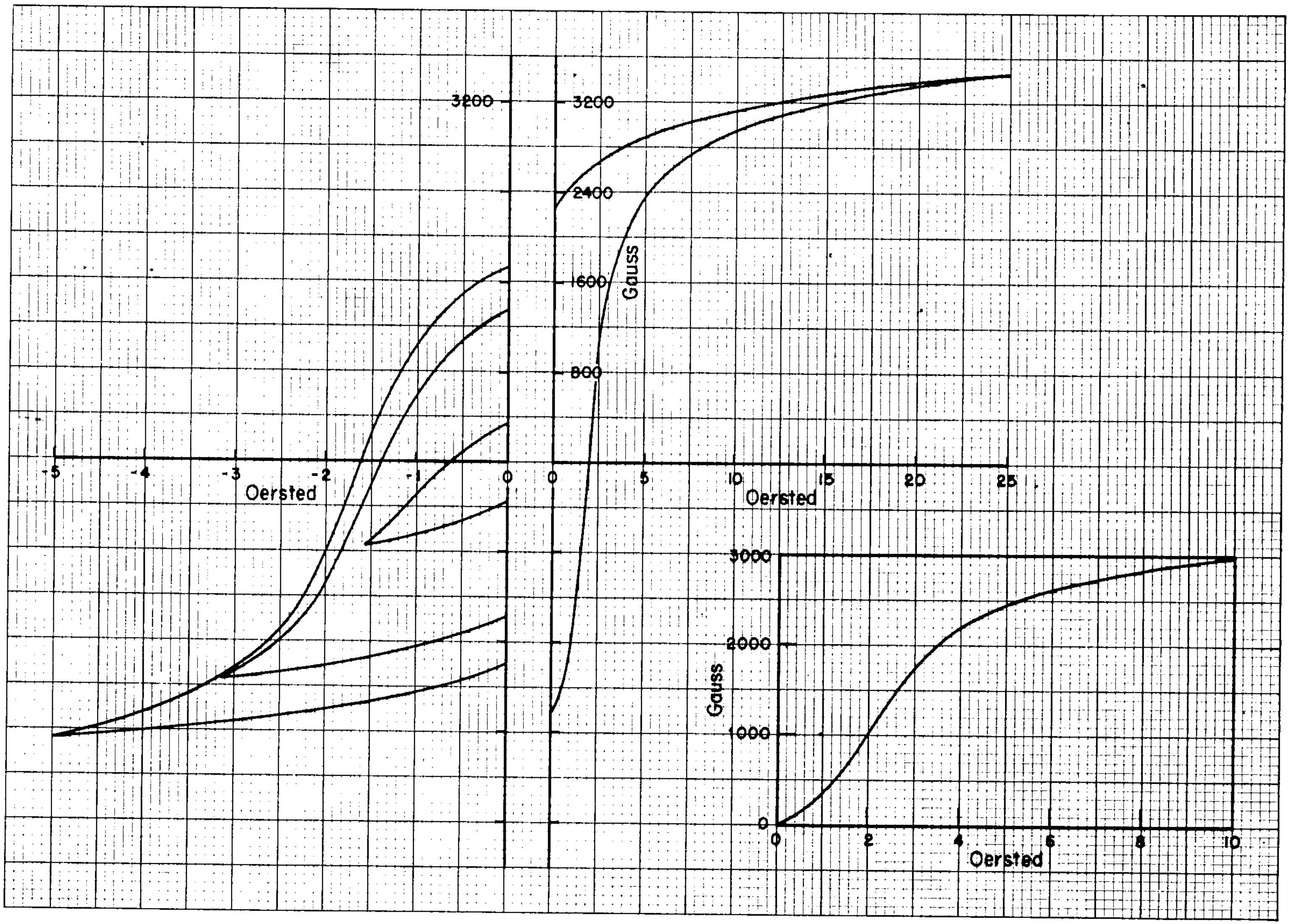
"Ferramic" Q

General Ceramics



IV B 8. Commercial Ferrite Ceramics

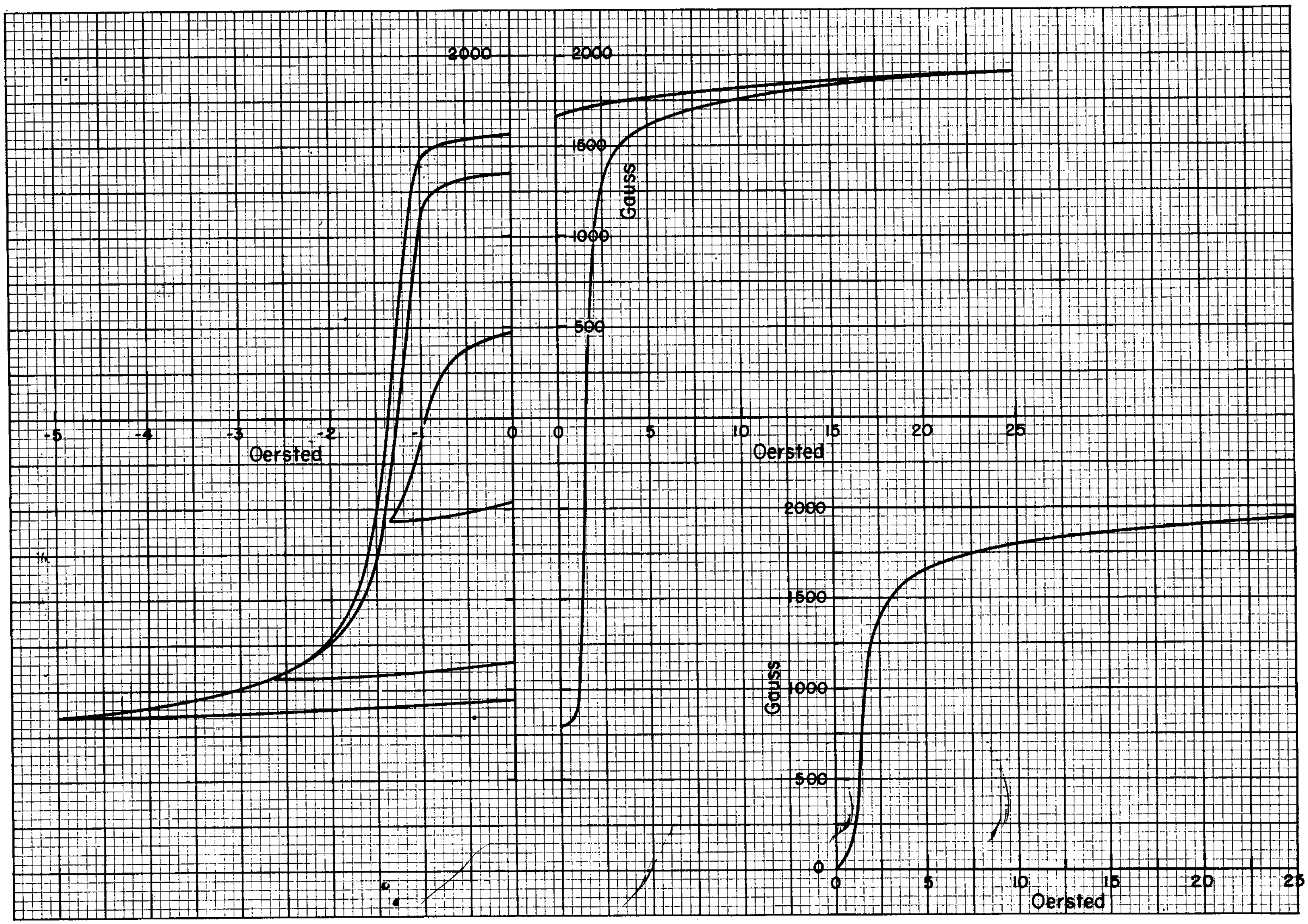
"Ferramic" MF 874 (T = 22°C) General Ceramics



IV B 8. Commercial Ferrite Ceramics

"Ferramic" 1326 B (T = 24°C)

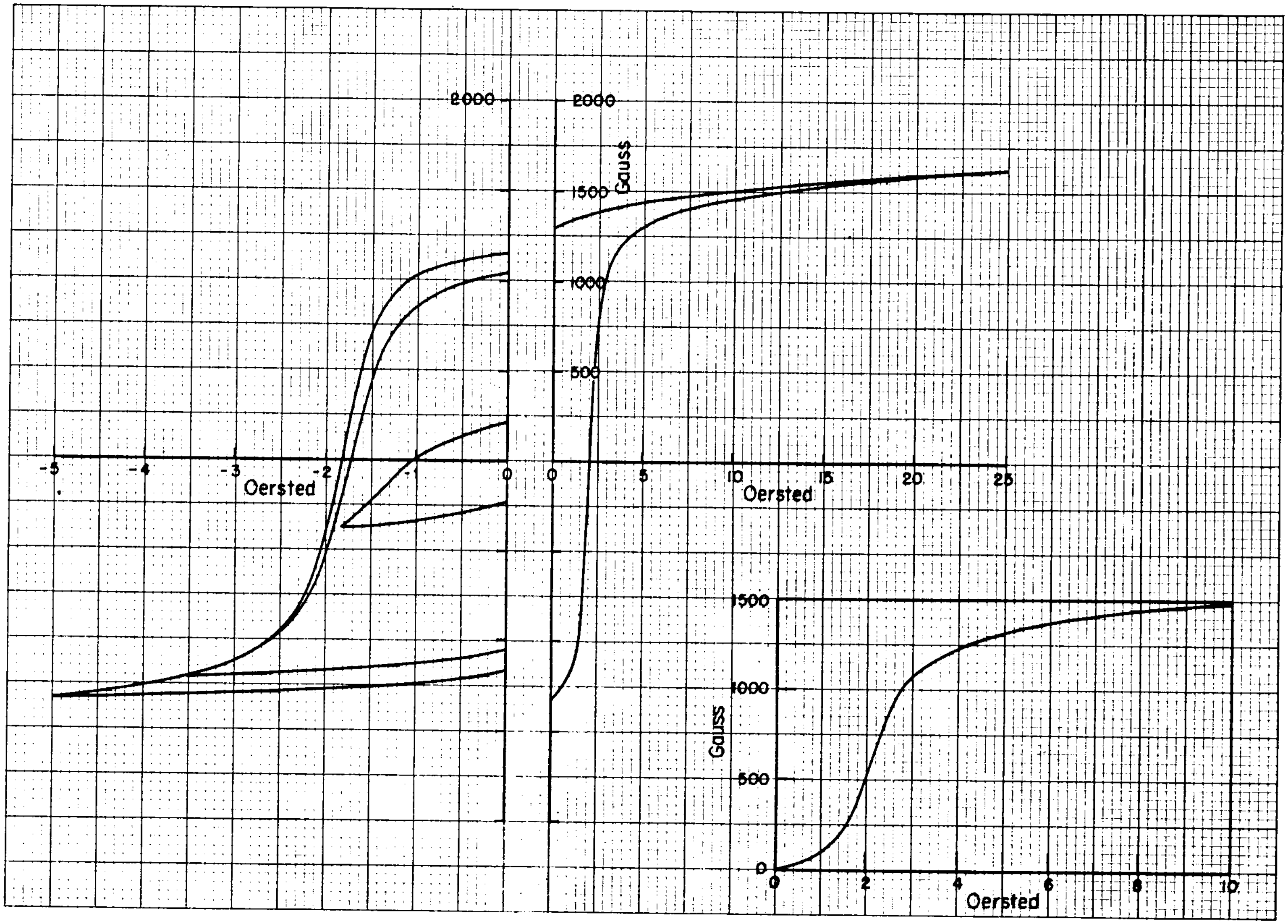
General Ceramics



IV B 8. Commercial Ferrite Ceramics

"Ferramic" 1331 (T = 25°C)

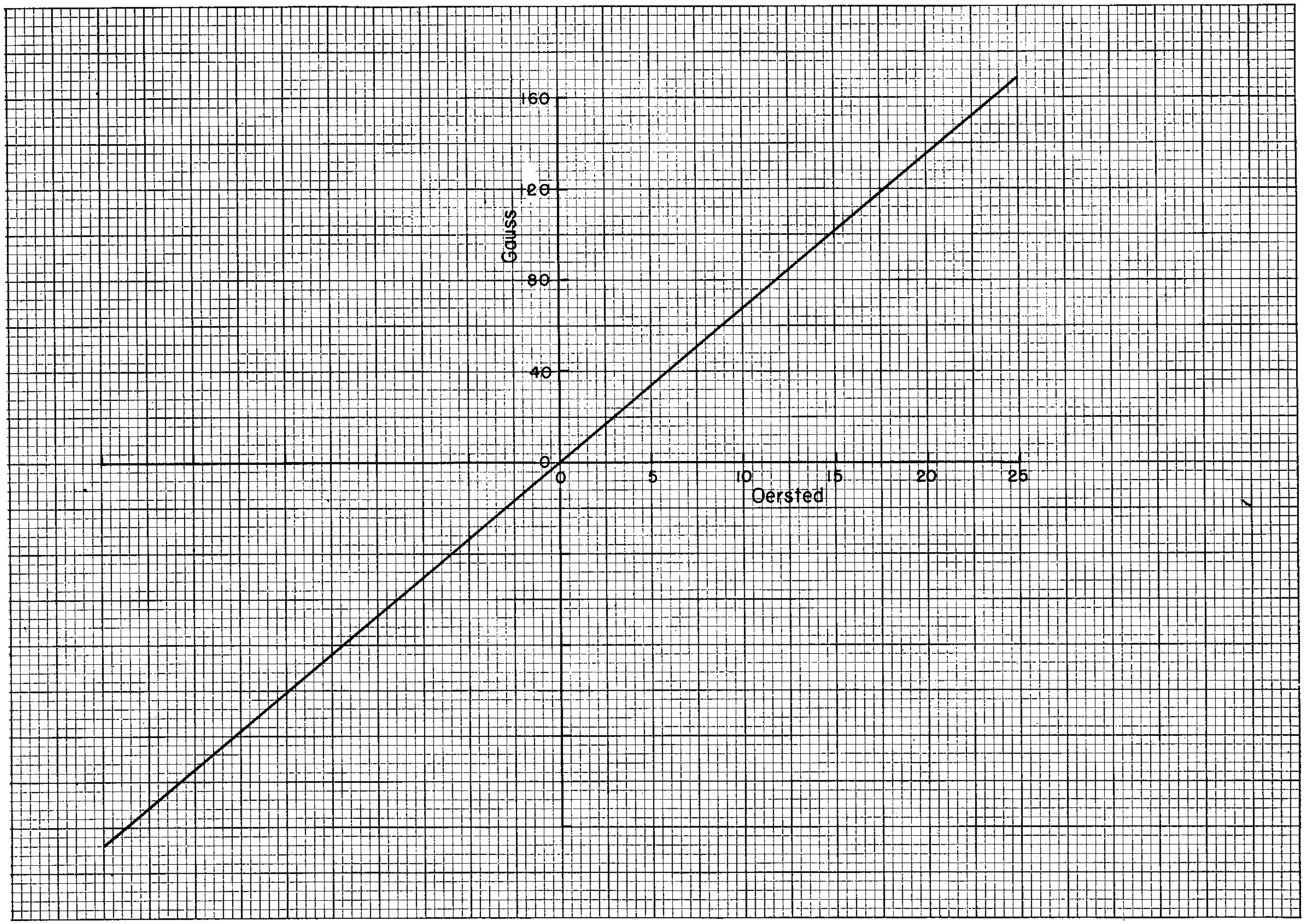
General Ceramics



IV B 9. Magnetic-Plastic Mixture

"Ferrotron" Core Material, Type 119

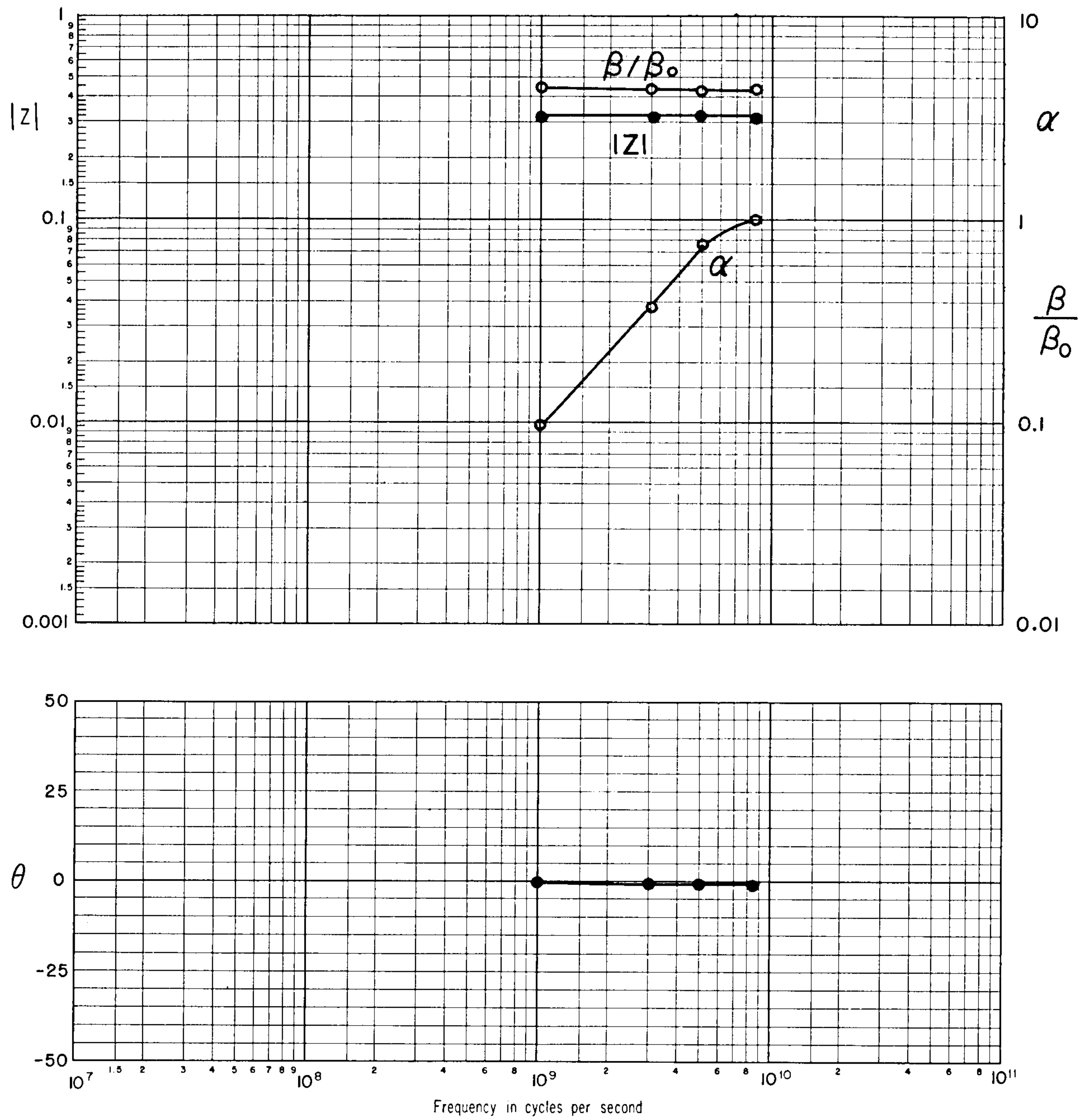
Polymer Corp.



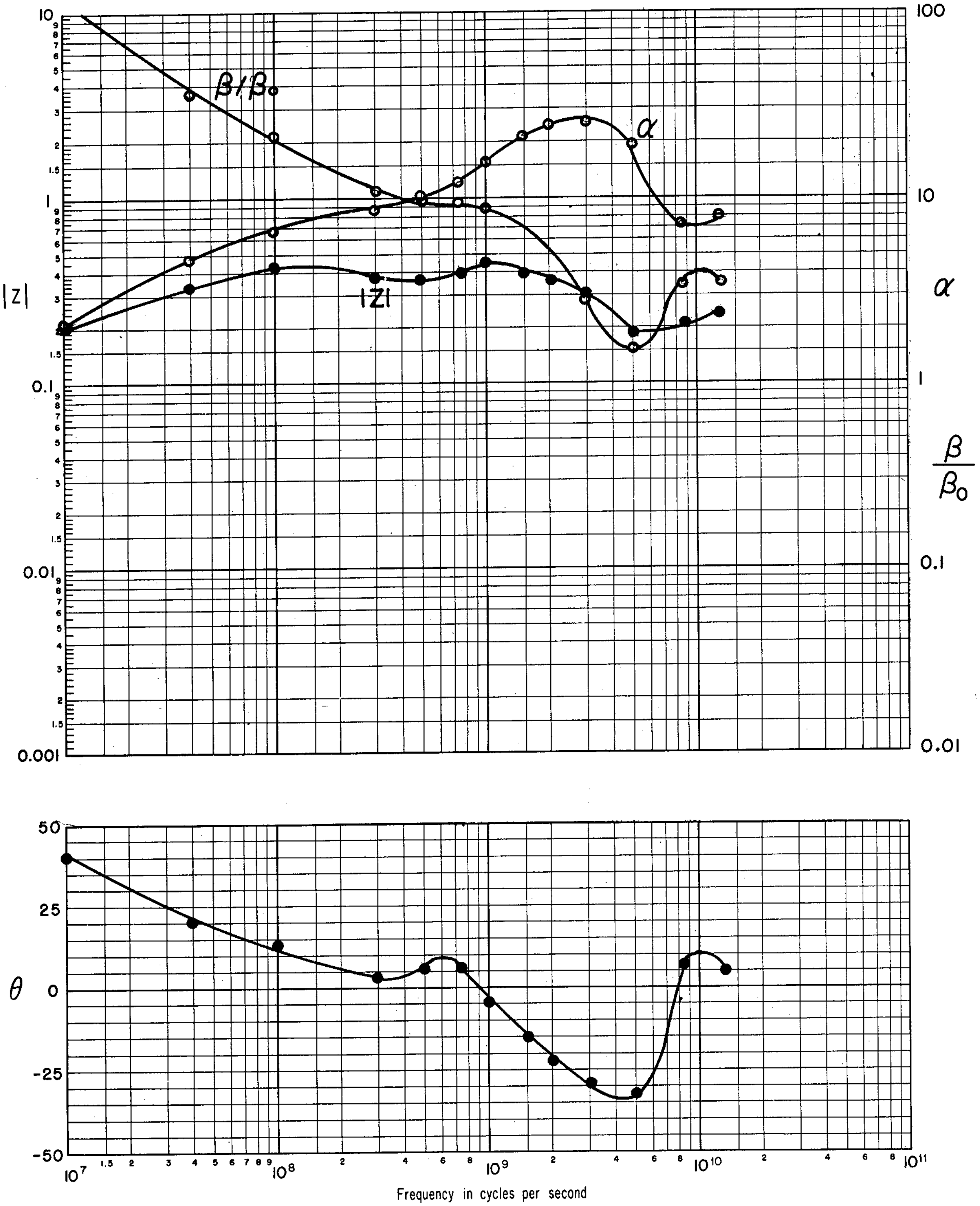
V. Attenuator Characteristics (Attenuation, Phase Shift, and Intrinsic Impedance)

A. Ferrites

$CoFe_2O_4$ Lab. Ins. Res.

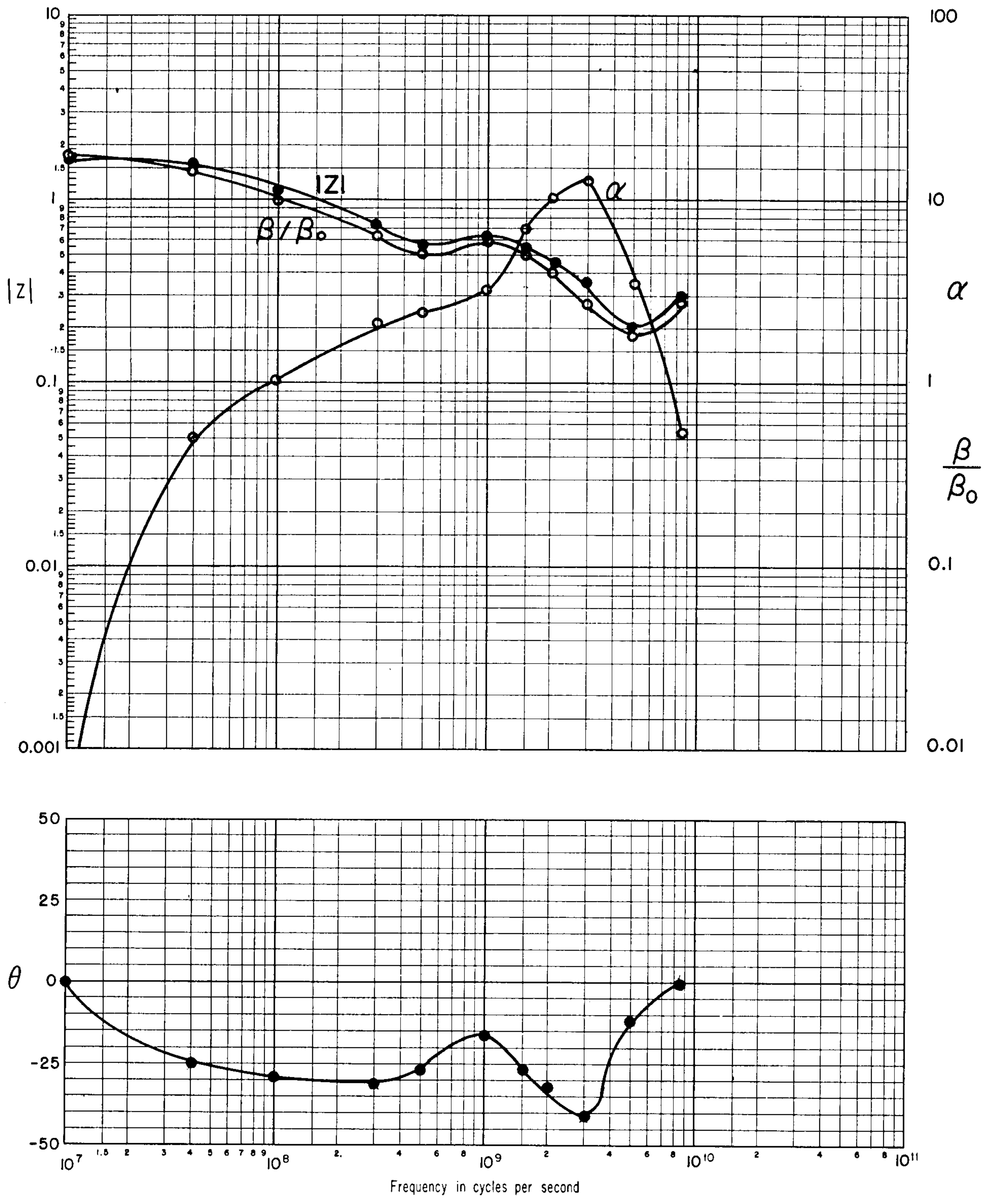


$MgFe_2O_4$ Lab. Ins. Res.

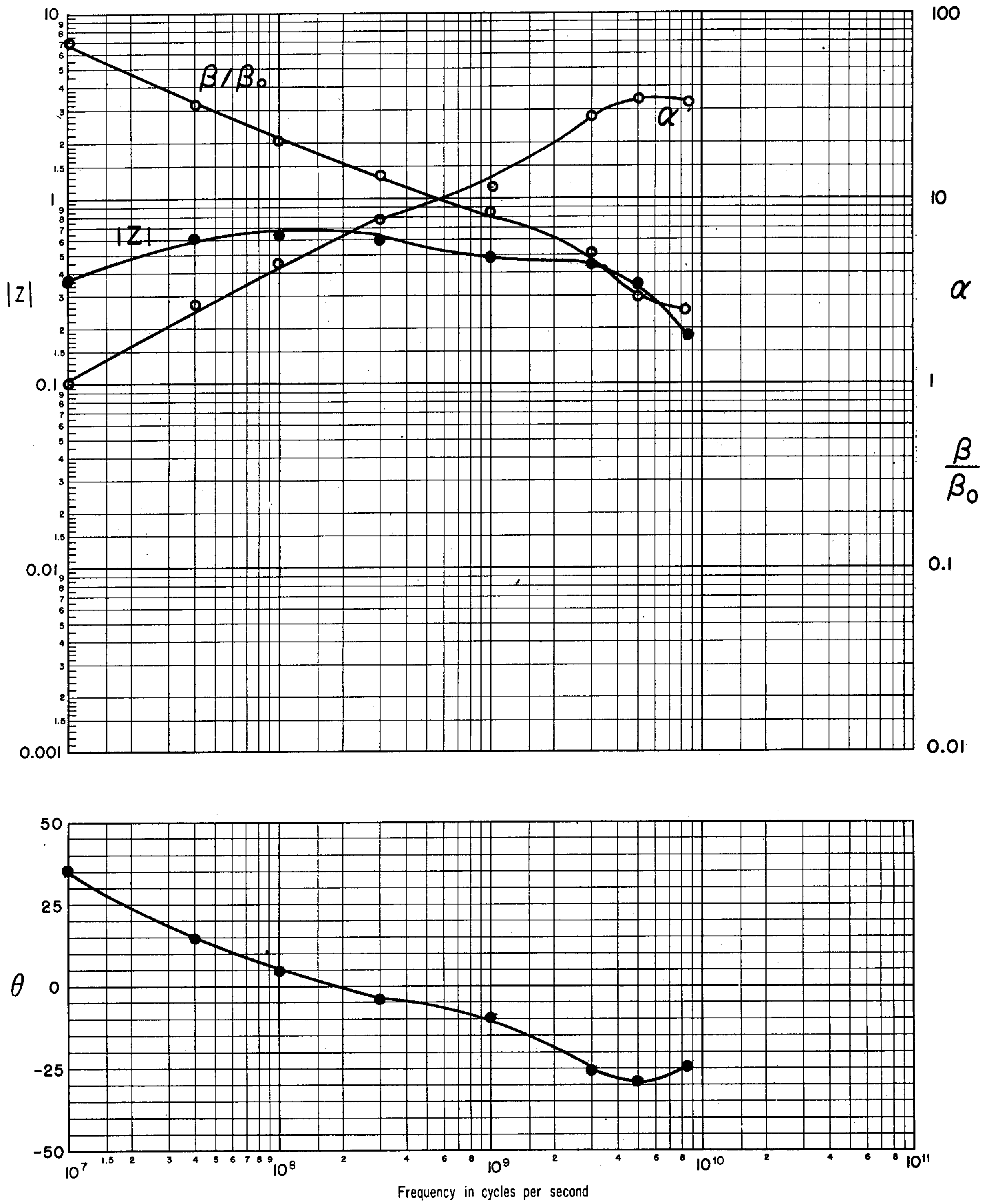


V A. Ferrites

$(MgO)_{0.58}(MnO)_{0.06}(Fe_2O_3)_{0.36}$ Lab. Ins. Res.



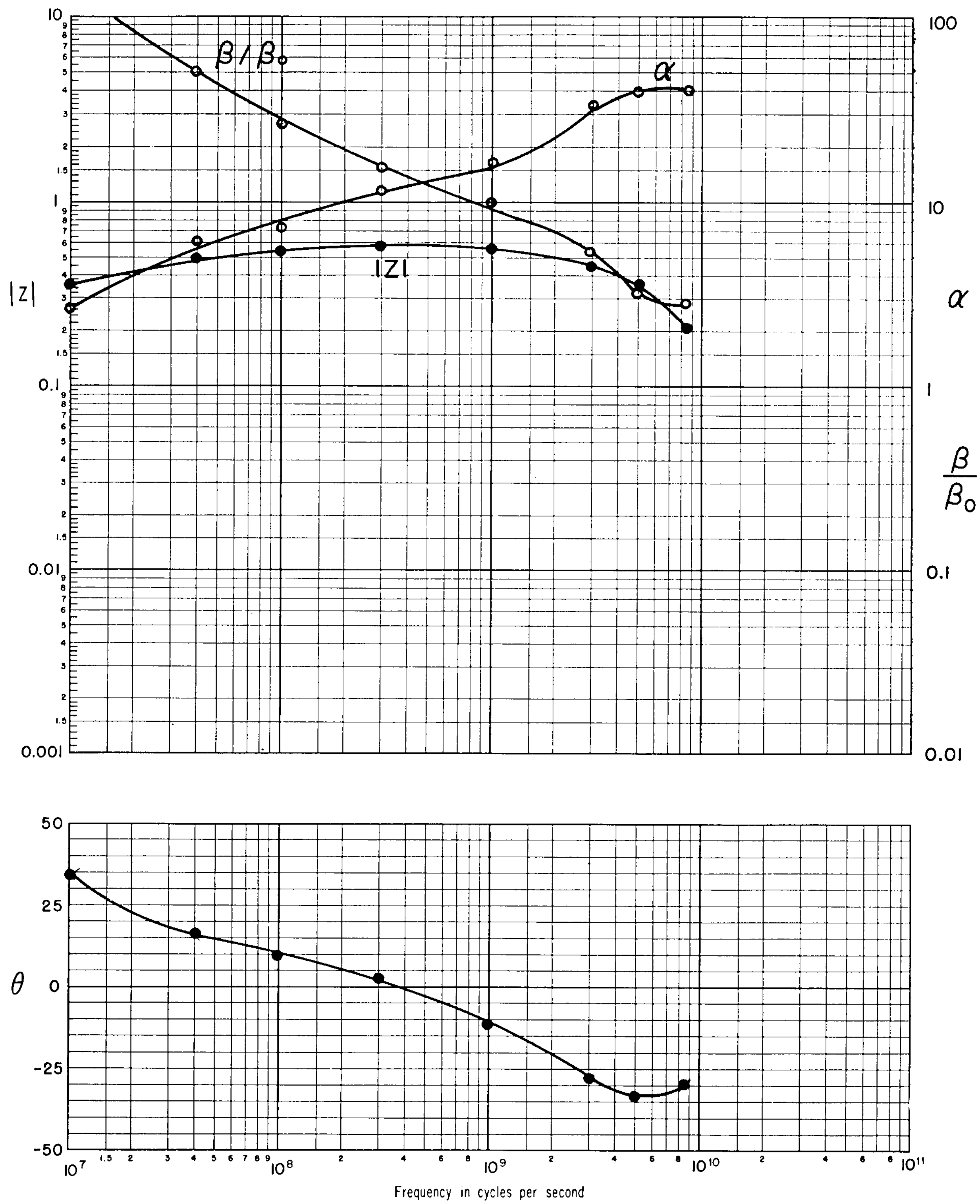
$NiFe_2O_4$ Lab. Ins. Res.



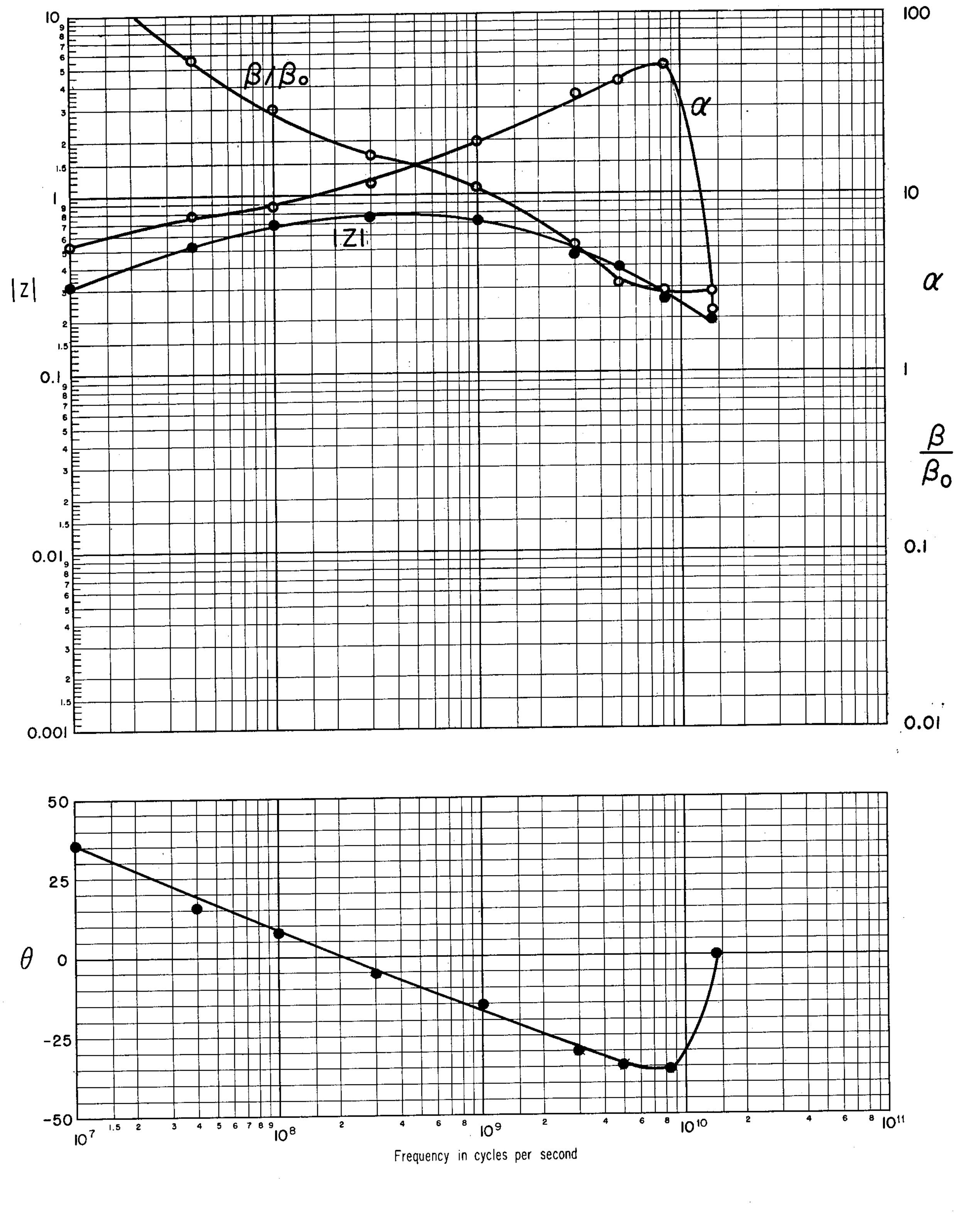
V A. Ferrites

$Ni_{0.9}Zn_{0.1}Fe_2O4$

Lab. Ins. Res.

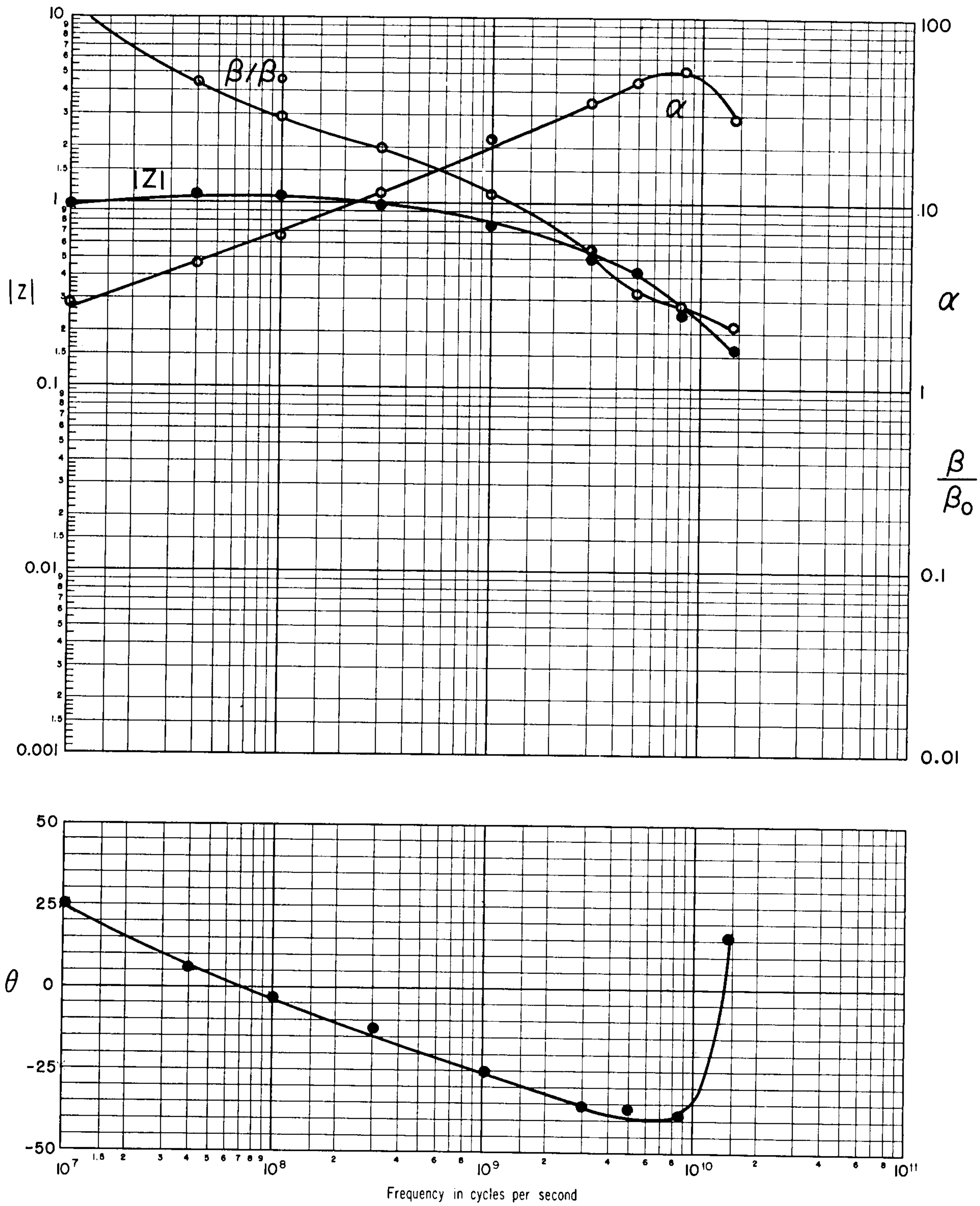


$Ni_{0.8}Zn_{0.2}Fe_2O_4$ Lab. Ins. Res.

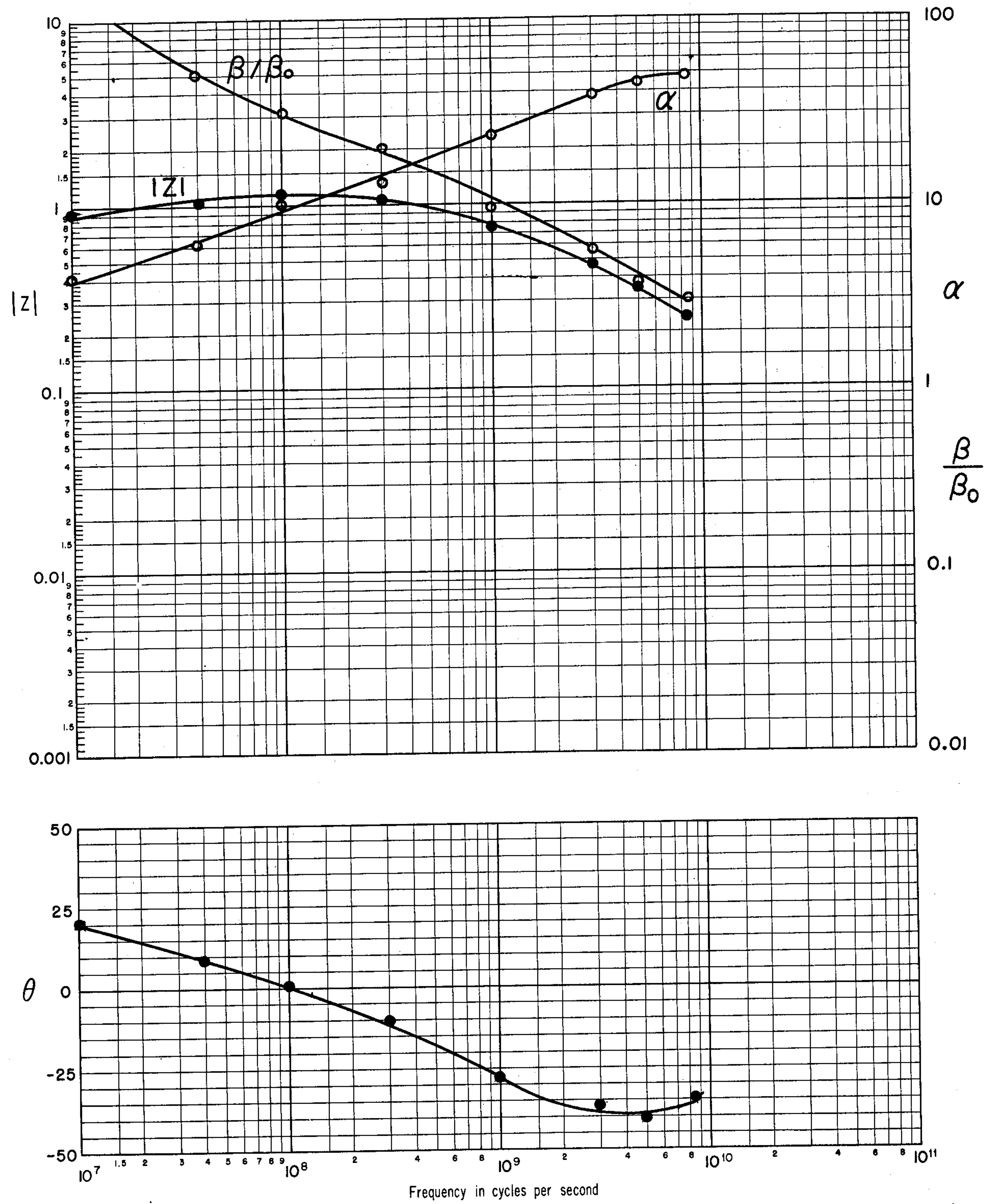


V A. Ferrites

$Ni_{0.7}Zn_{0.3}Fe_2O_4$ Lab. Ins. Res.

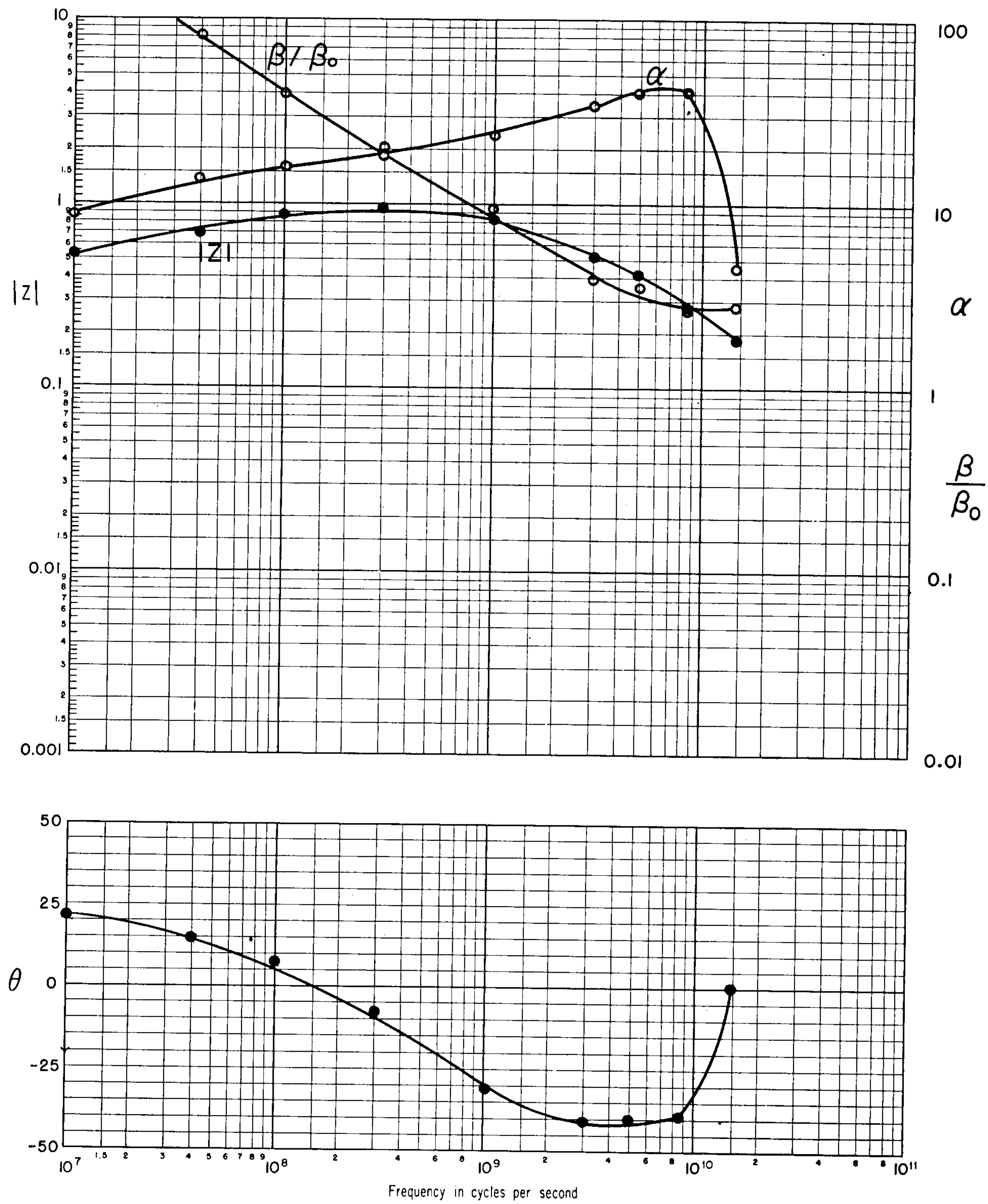


$Ni_{0.6}Zn_{0.4}Fe_2O_4$ Lab. Ins. Res.



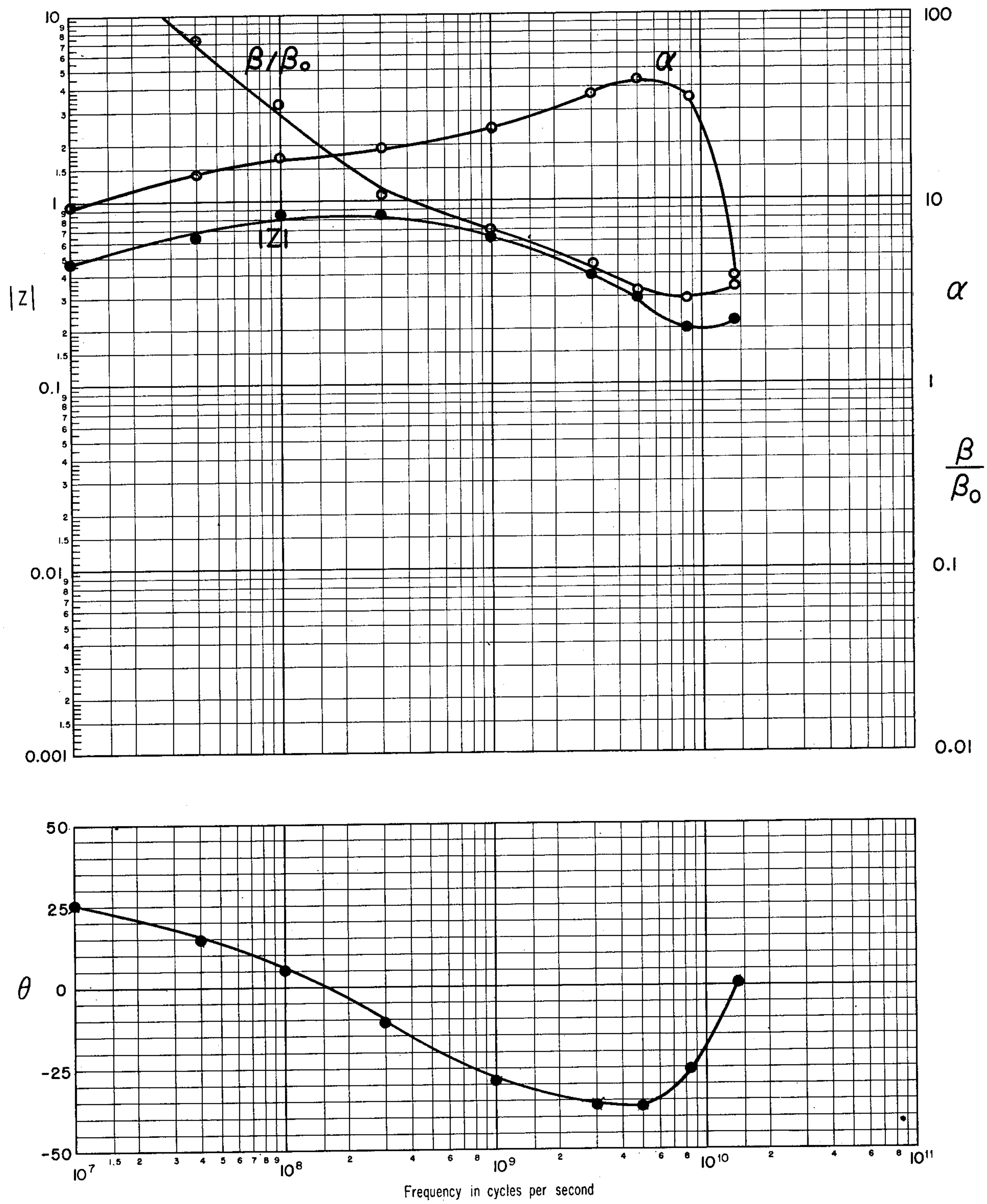
V A. Ferrites

$Ni_{0.5}Zn_{0.5}Fe_2O_4$ Lab. Ins. Res.

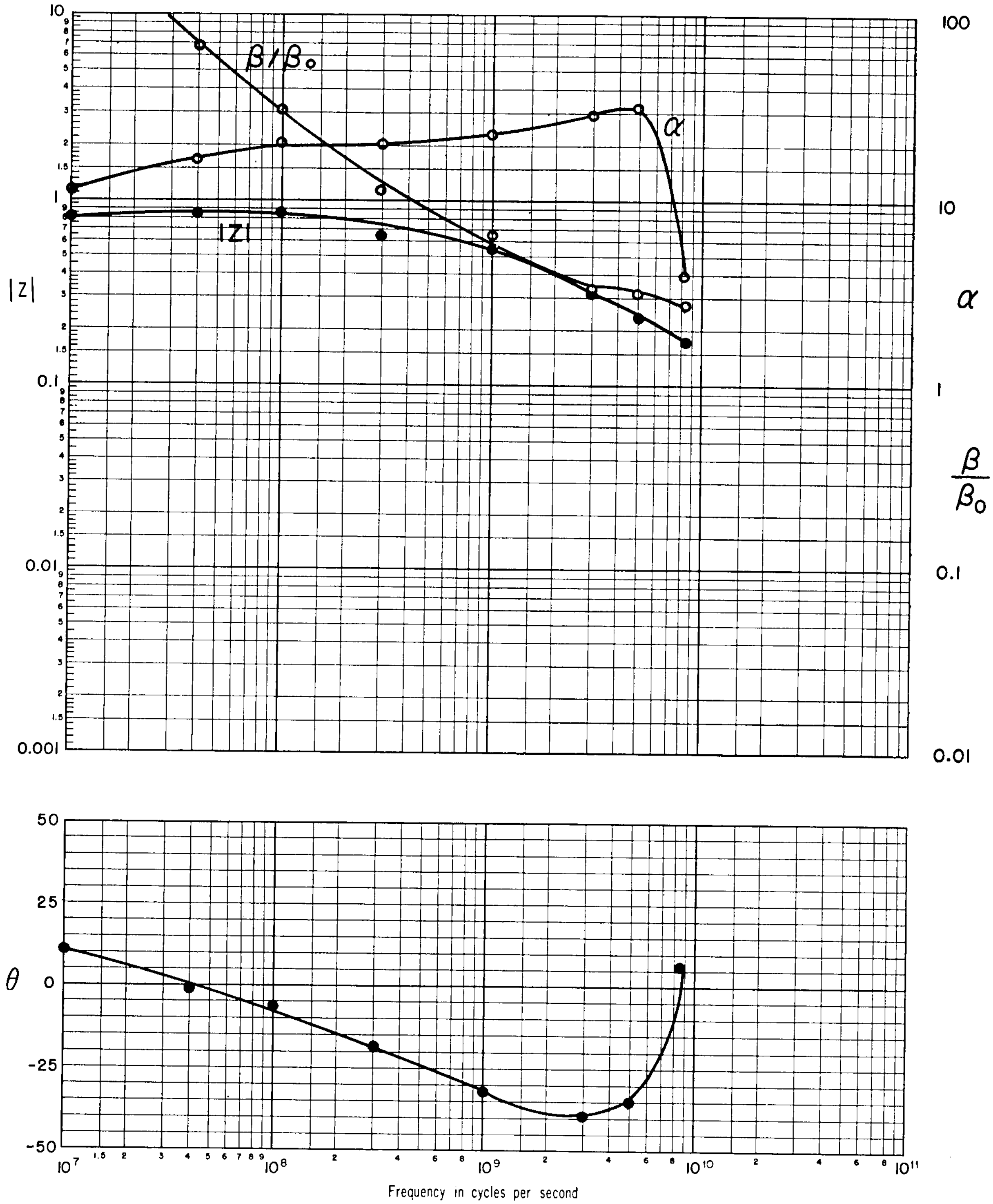


$Ni_{0.4}Zn_{0.6}Fe_2O_4$

Lab. Ins. Res.

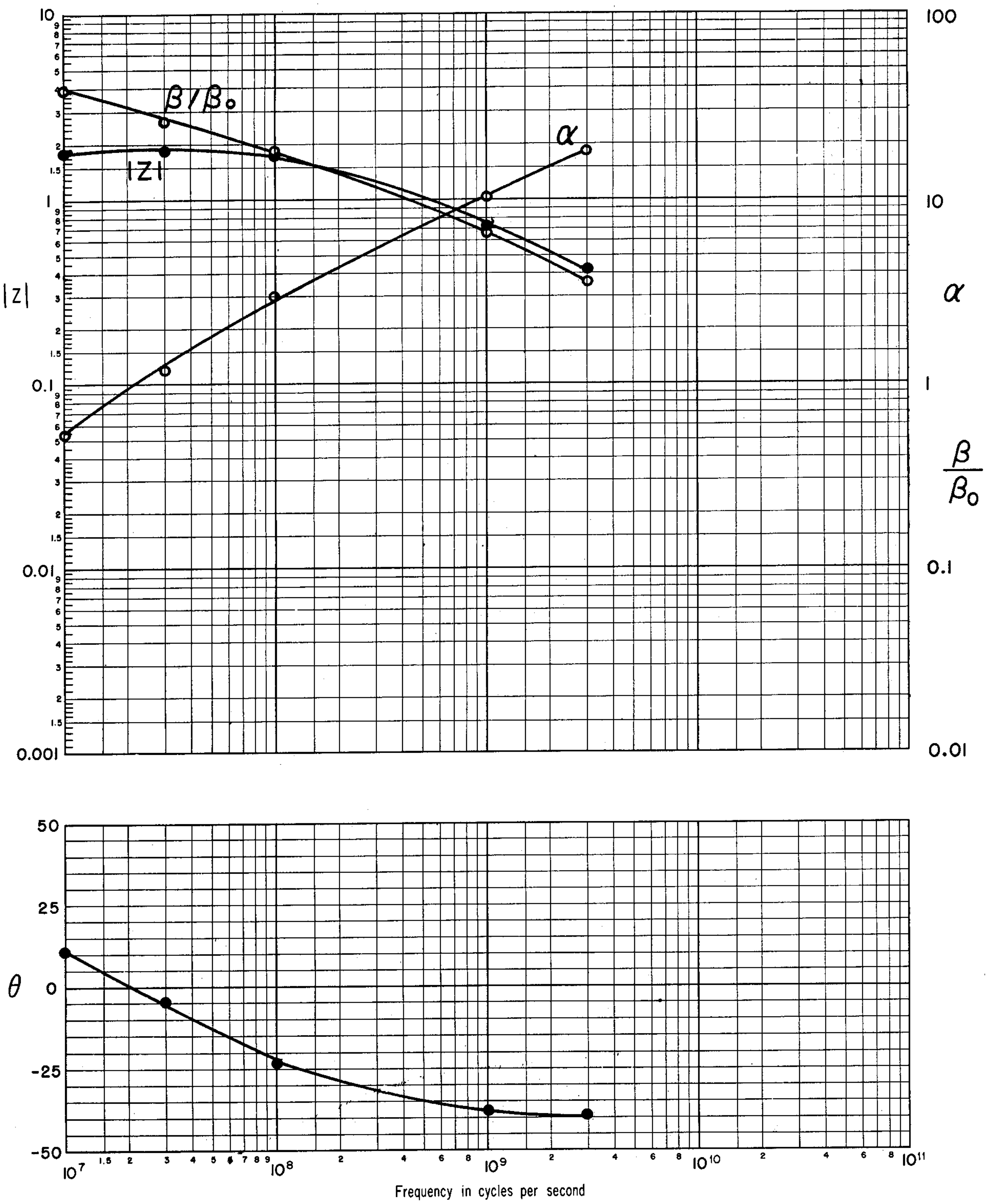


$Ni_{0.3}Zn_{0.7}Fe_2O_4$ Lab. Ins. Res.



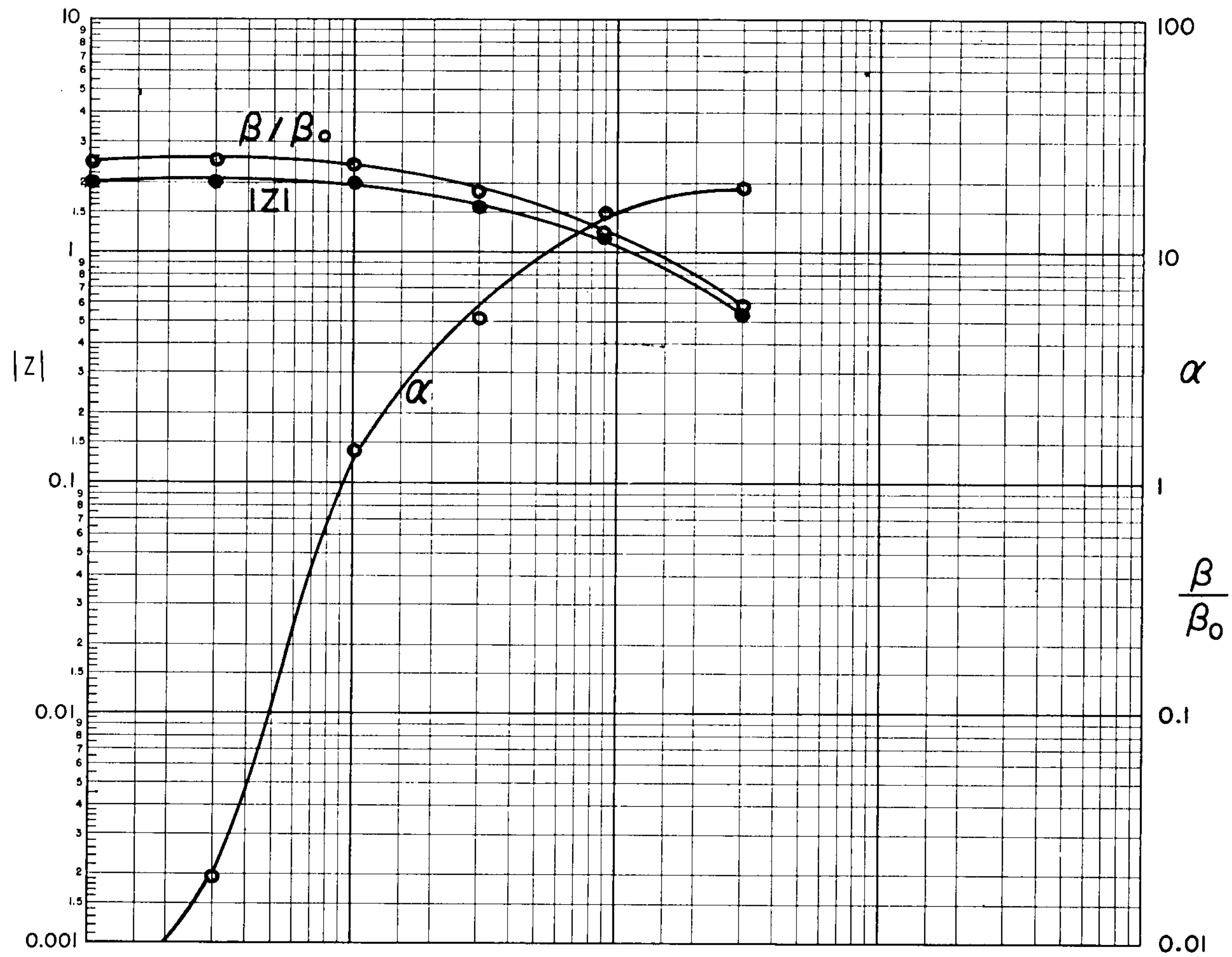
"Crowloy" 20

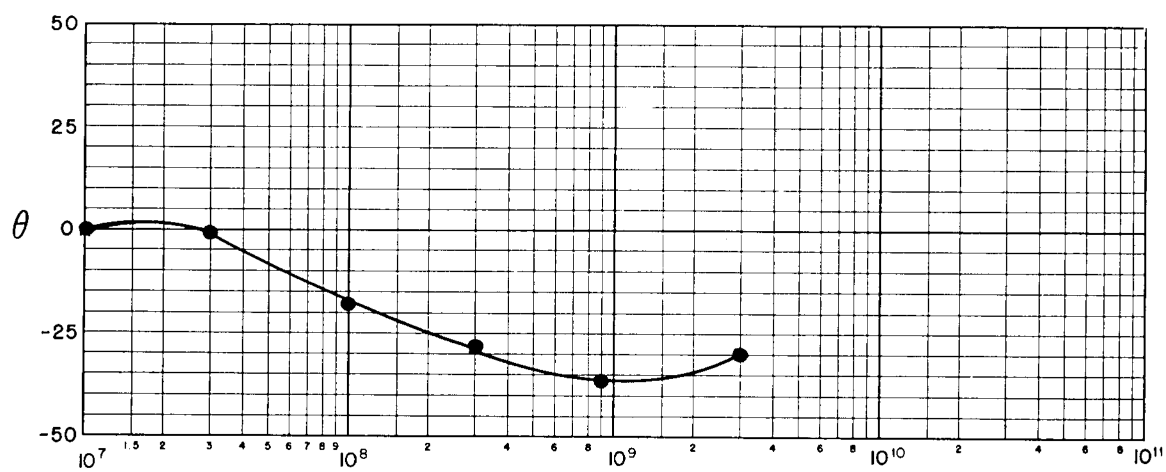
Crowley



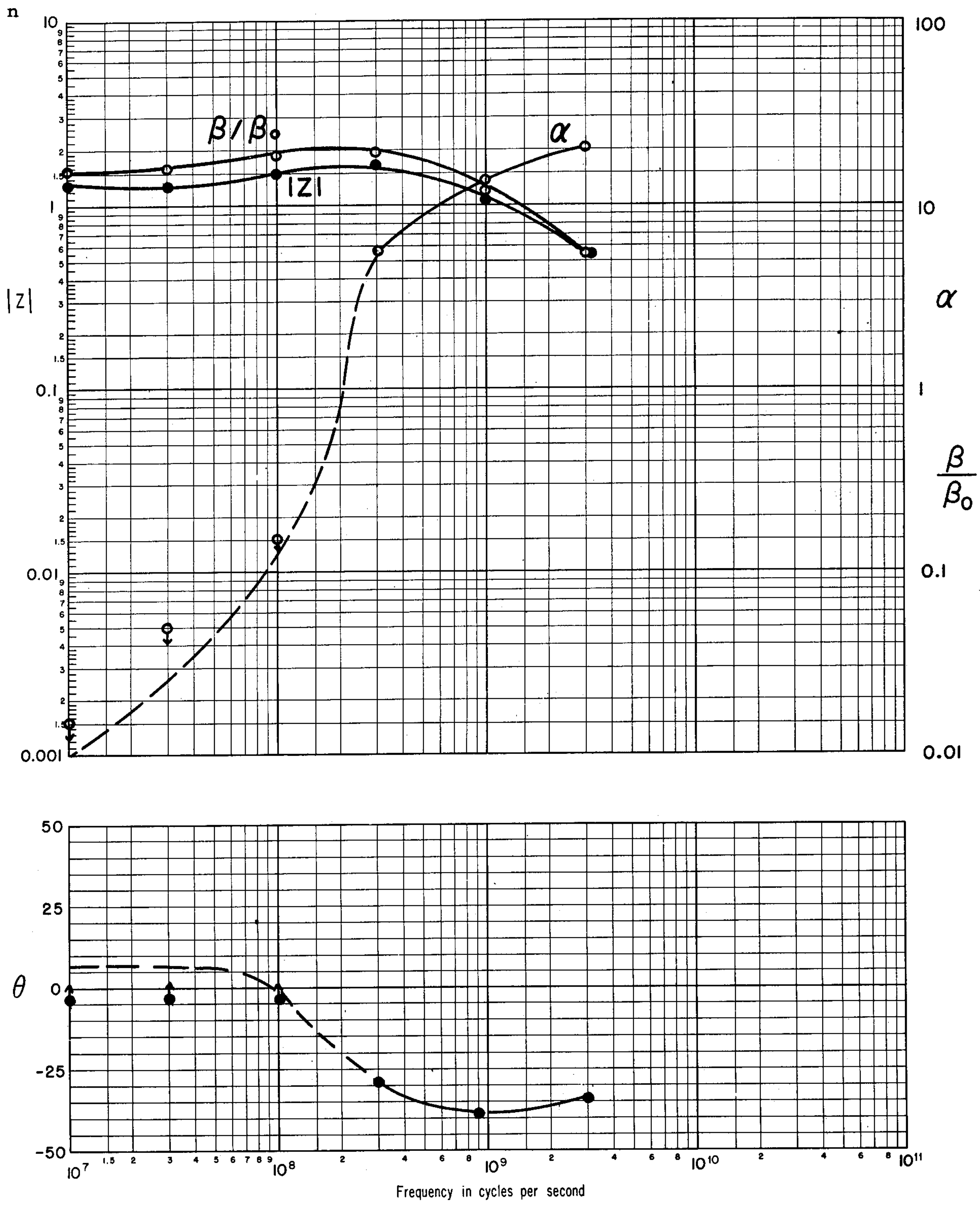
"Crowloy" BX113

Crowley



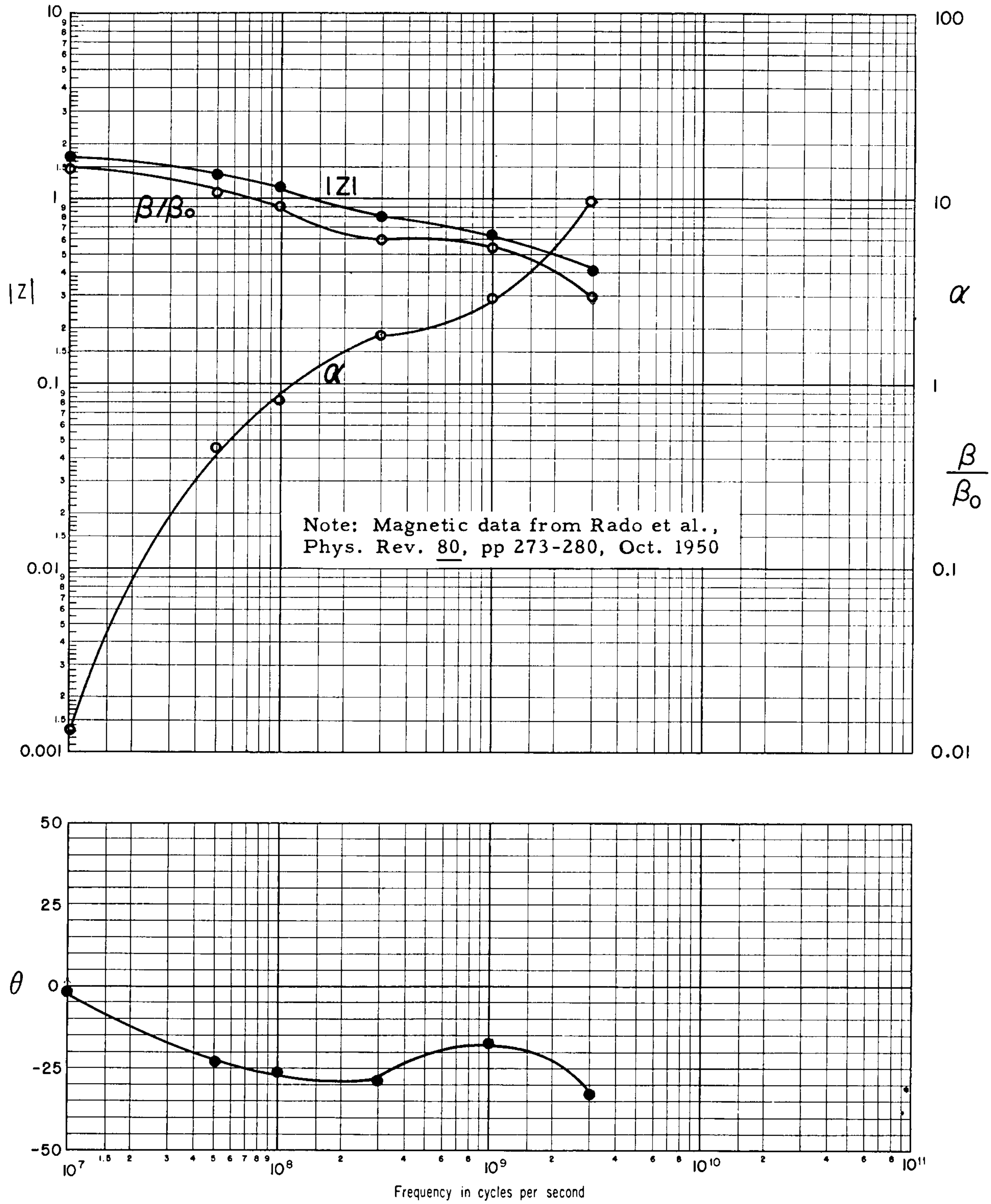


"Crowloy" BX114 Crowley

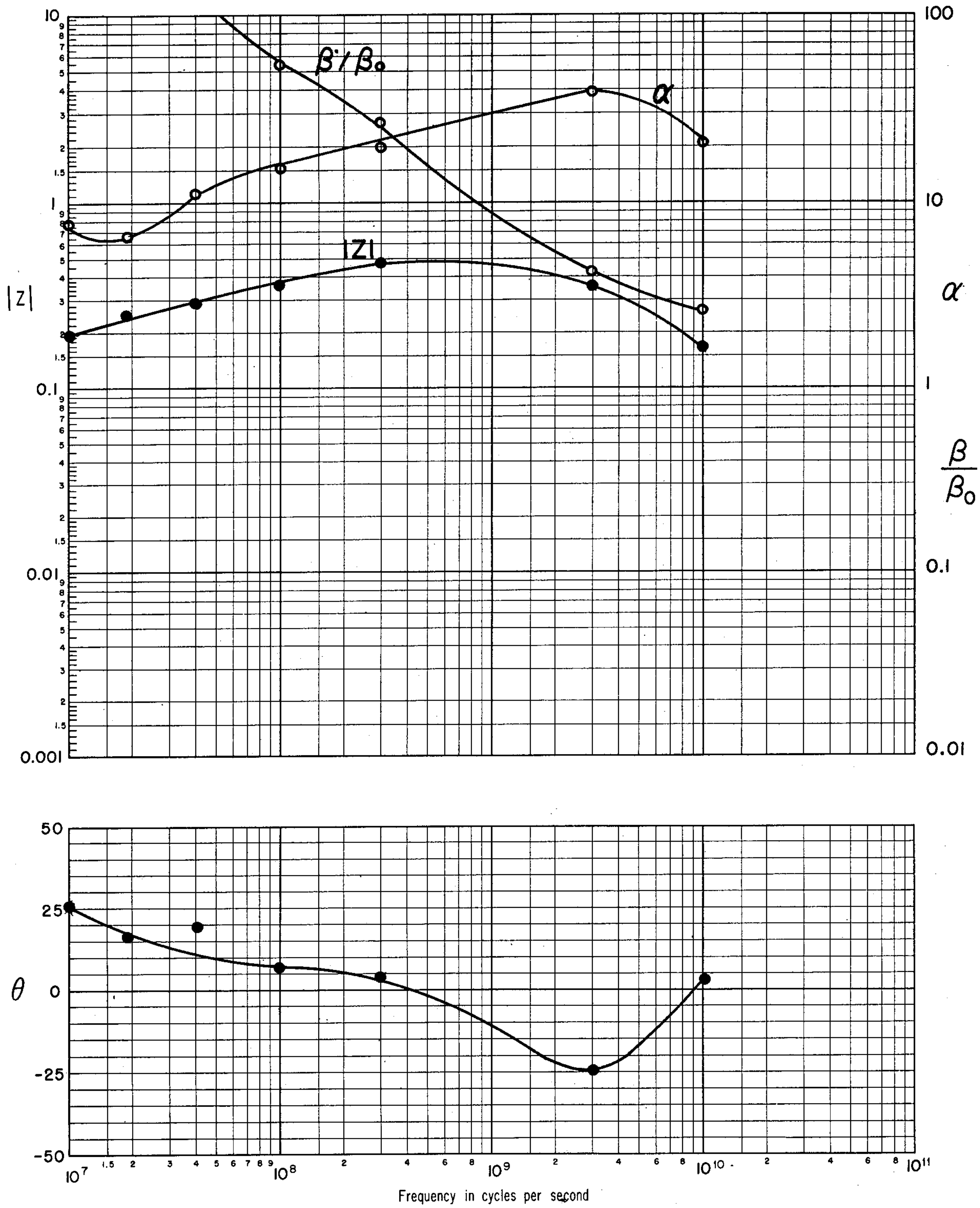


"Ferramic" A

General Ceramics



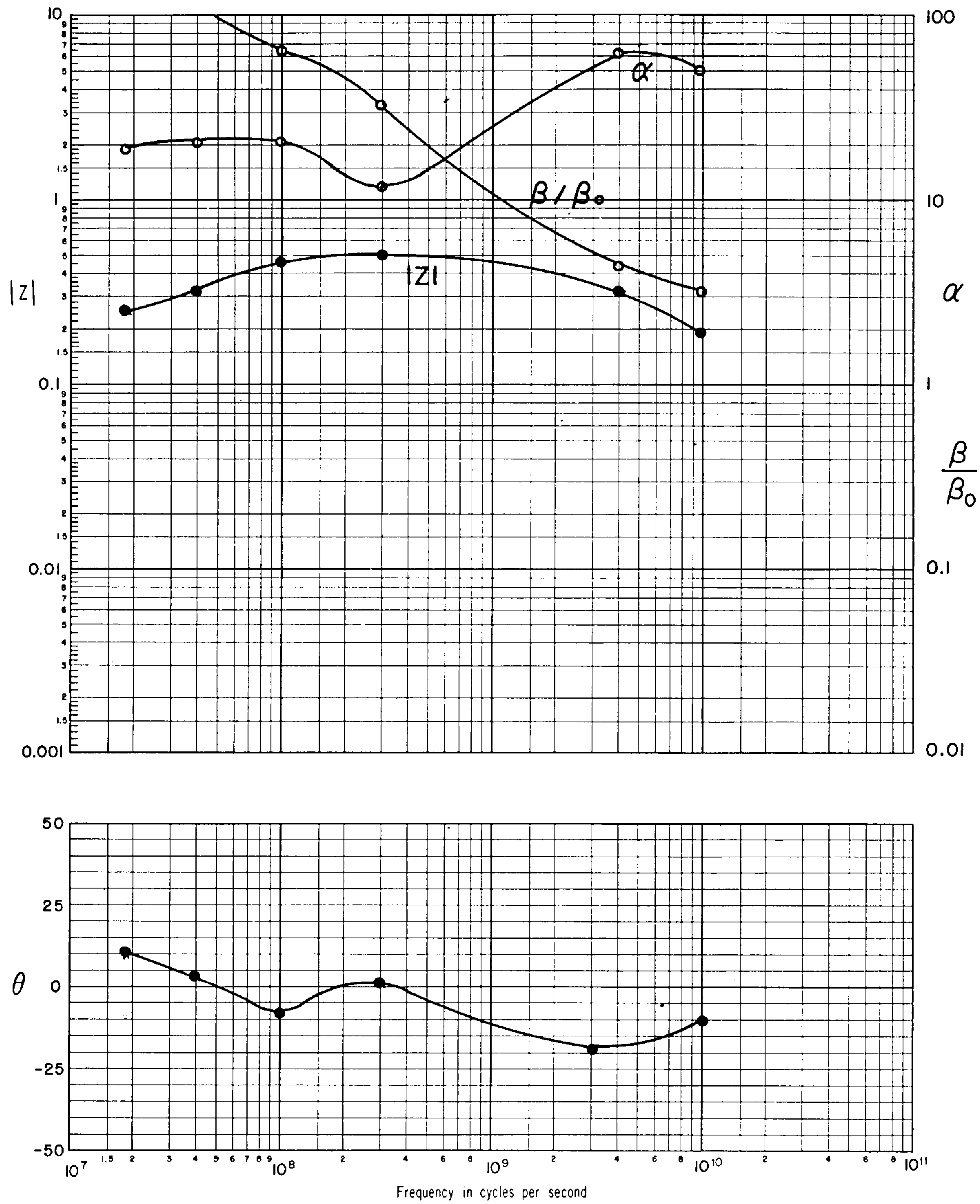
"Ferramic" B — V A. Ferrites — General Ceramics



V A. Ferrites

"Ferramic" C

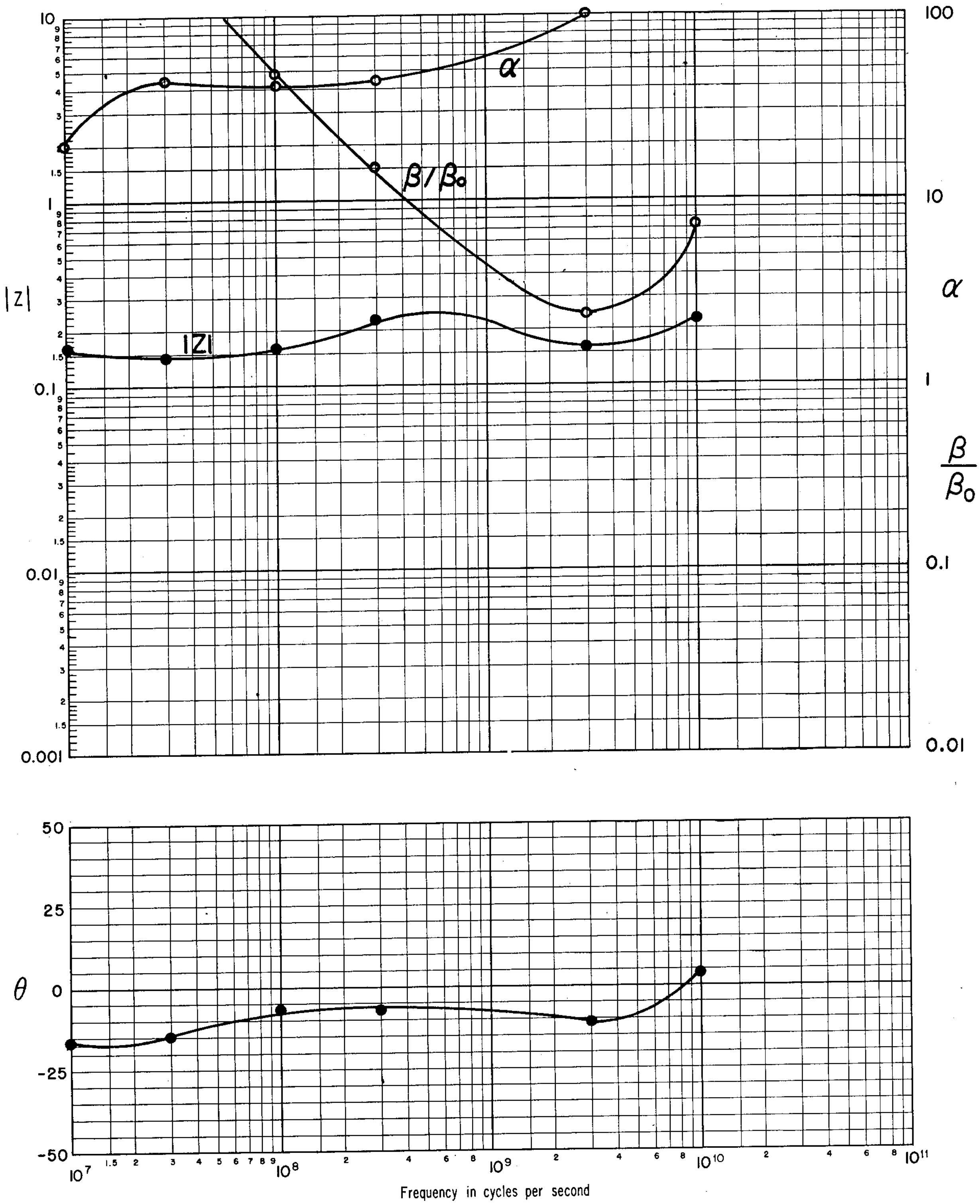
General Ceramics



V A. Ferrites

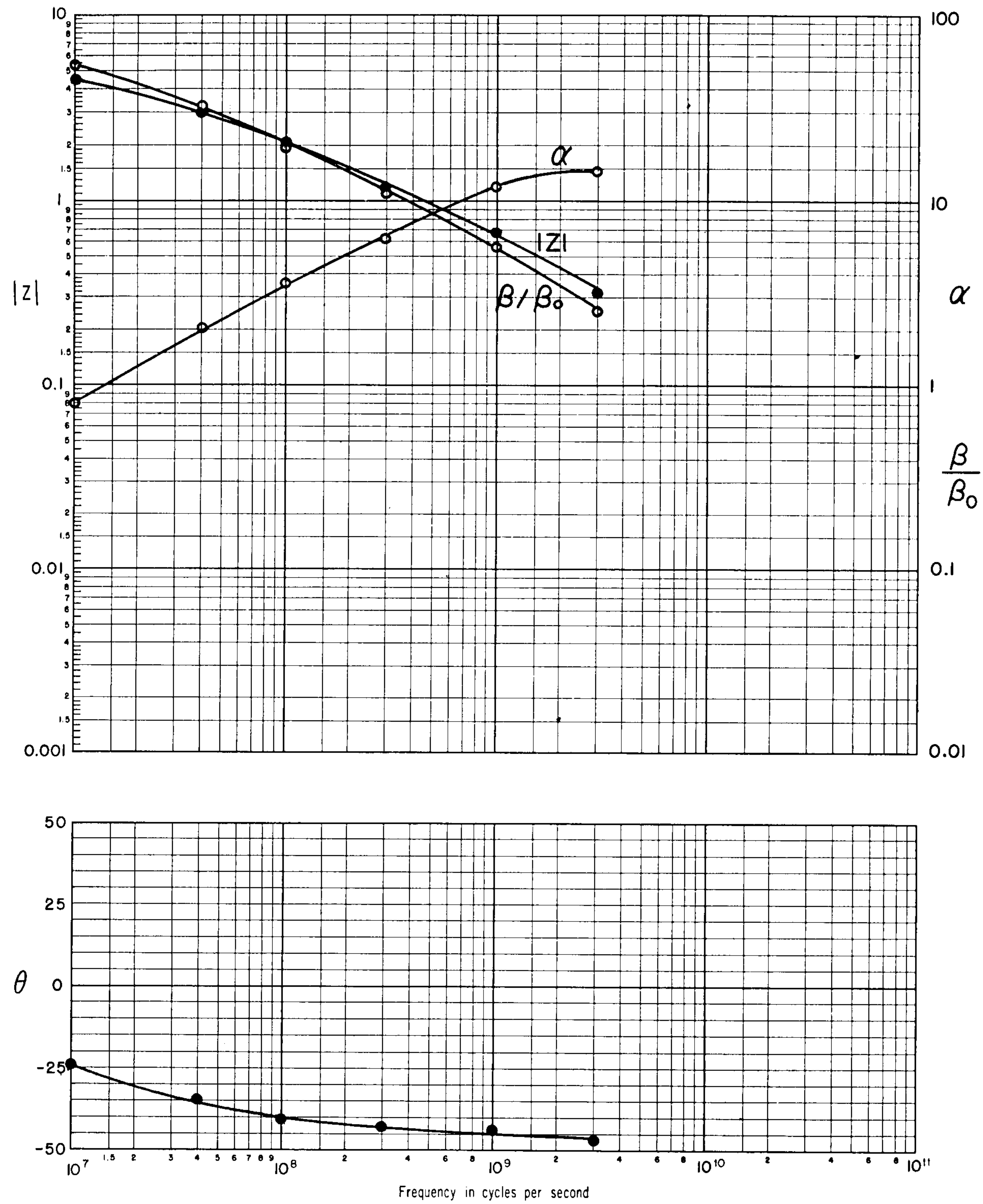
"Ferramic" D

General Ceramics



"Ferramic" E

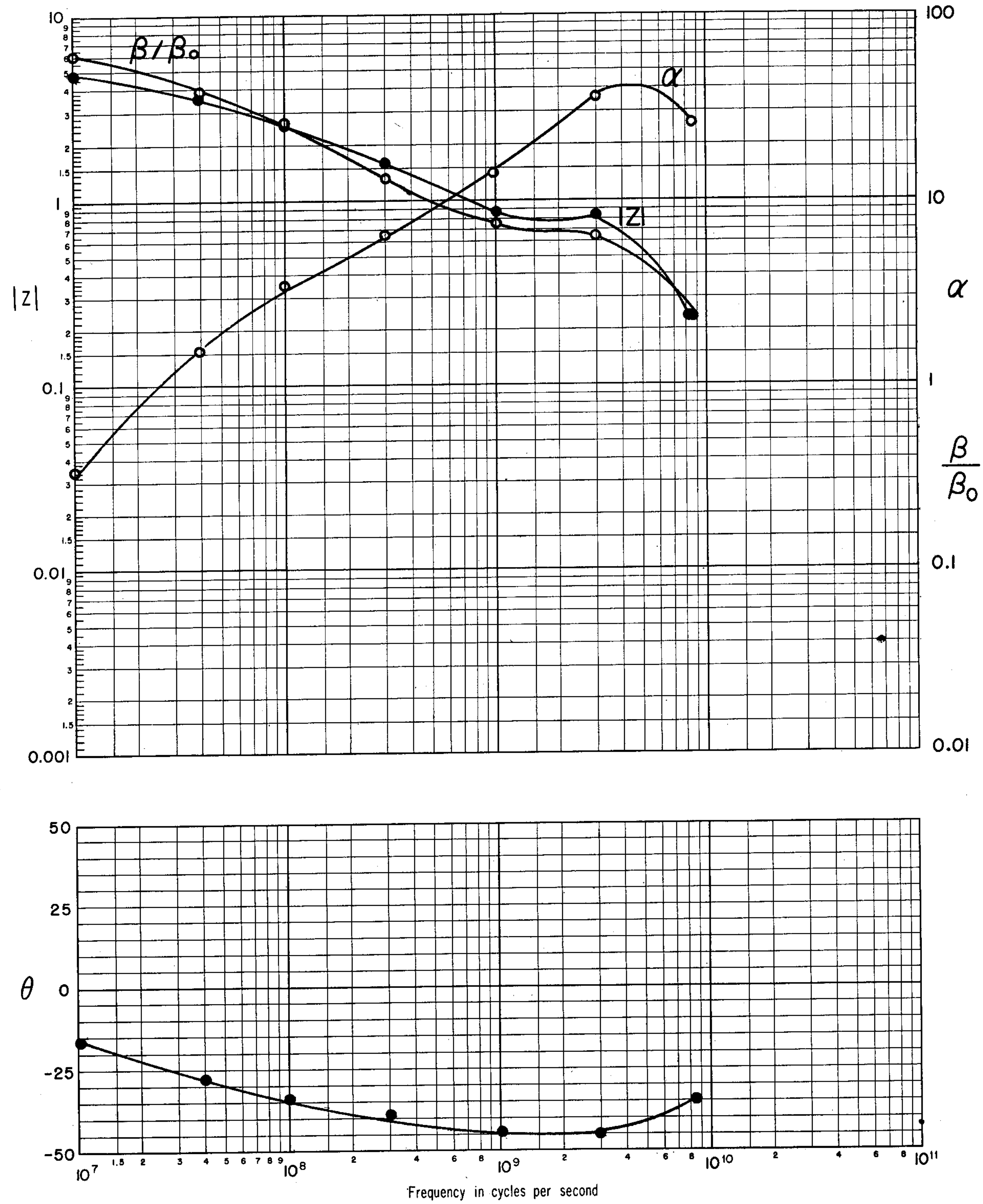
General Ceramics



V A. Ferrites

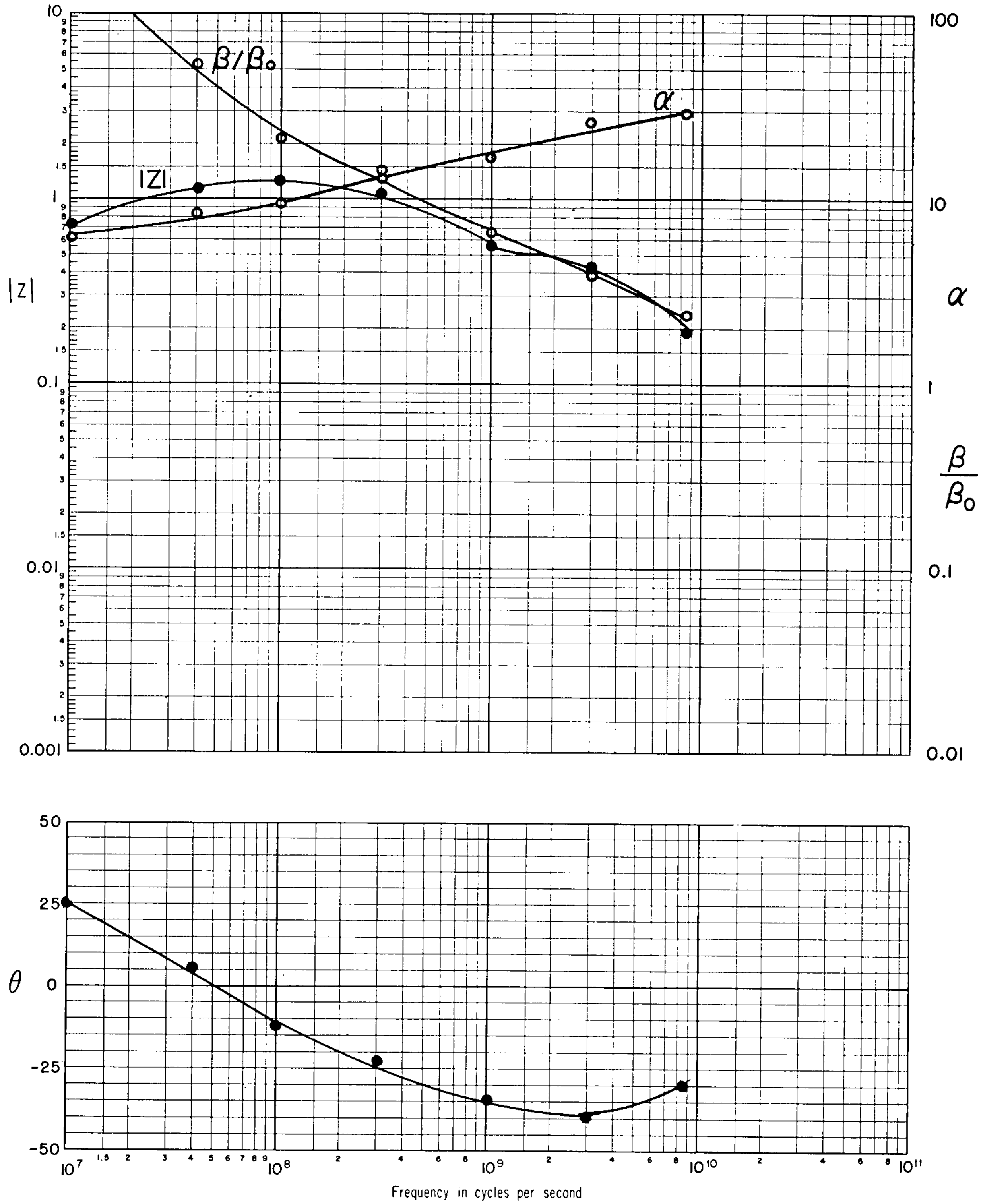
"Ferramic" G

General Ceramics



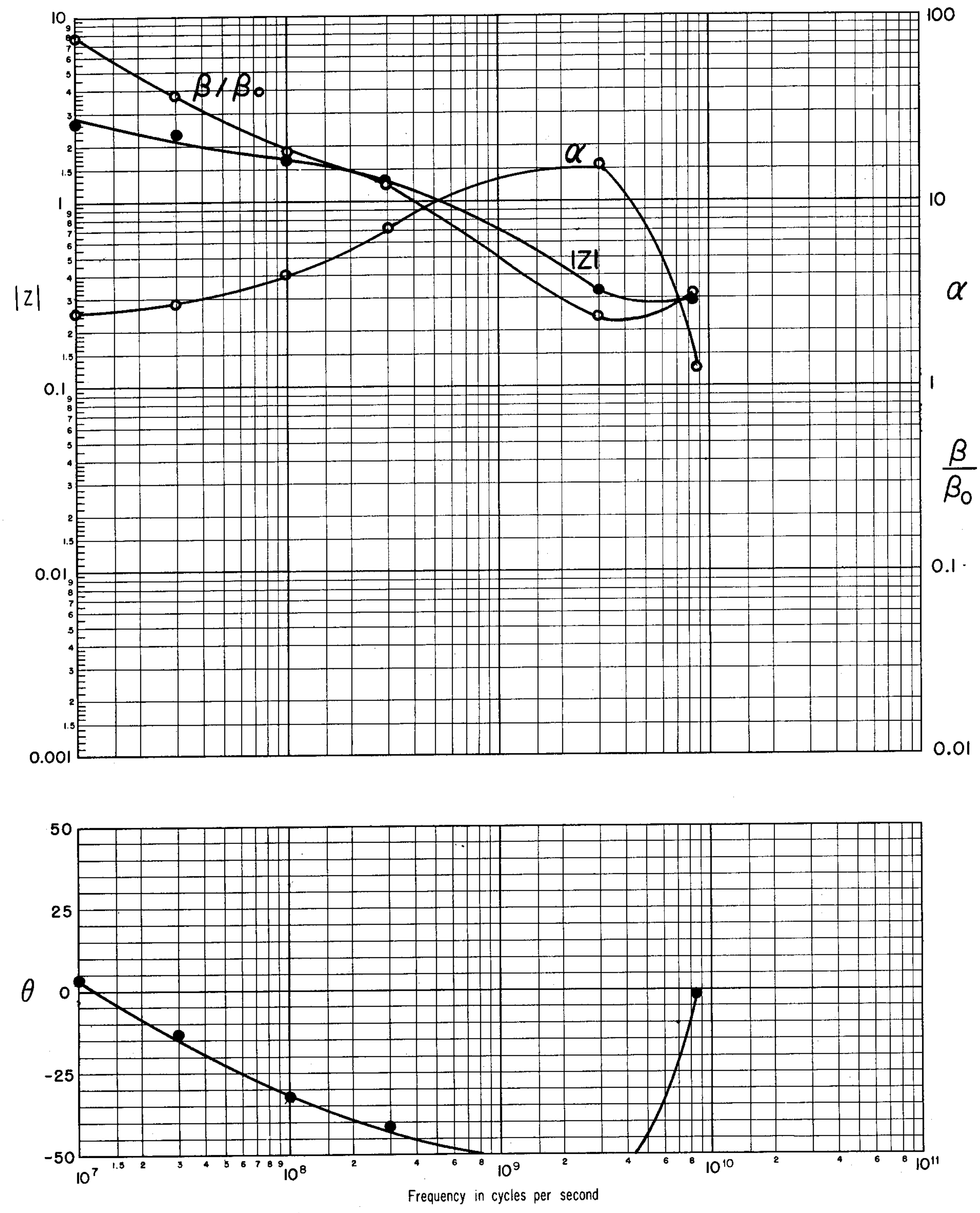
"Ferramic"H

General Ceramics



"Ferramic" I

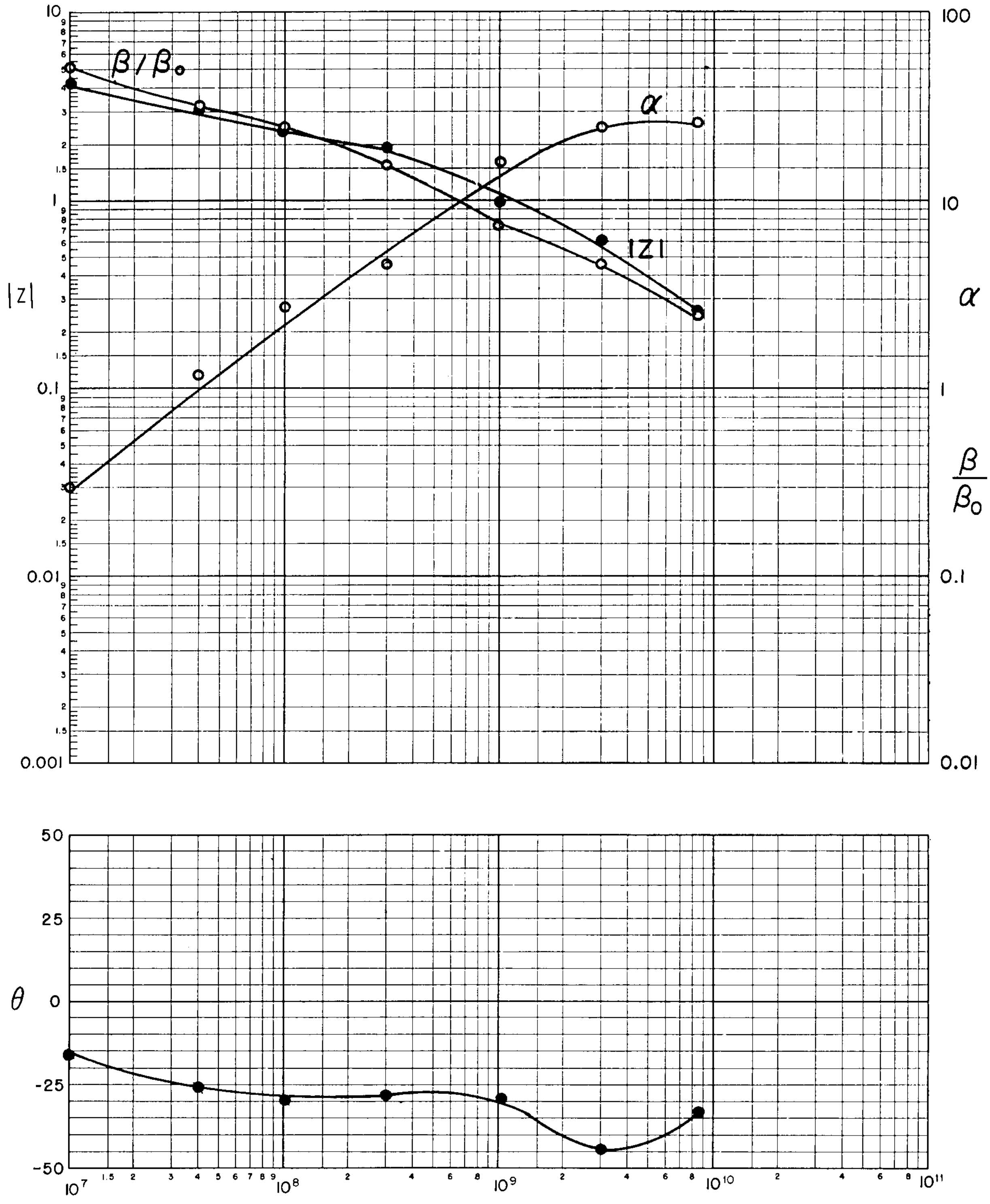
General Ceramics



V A. Ferrites

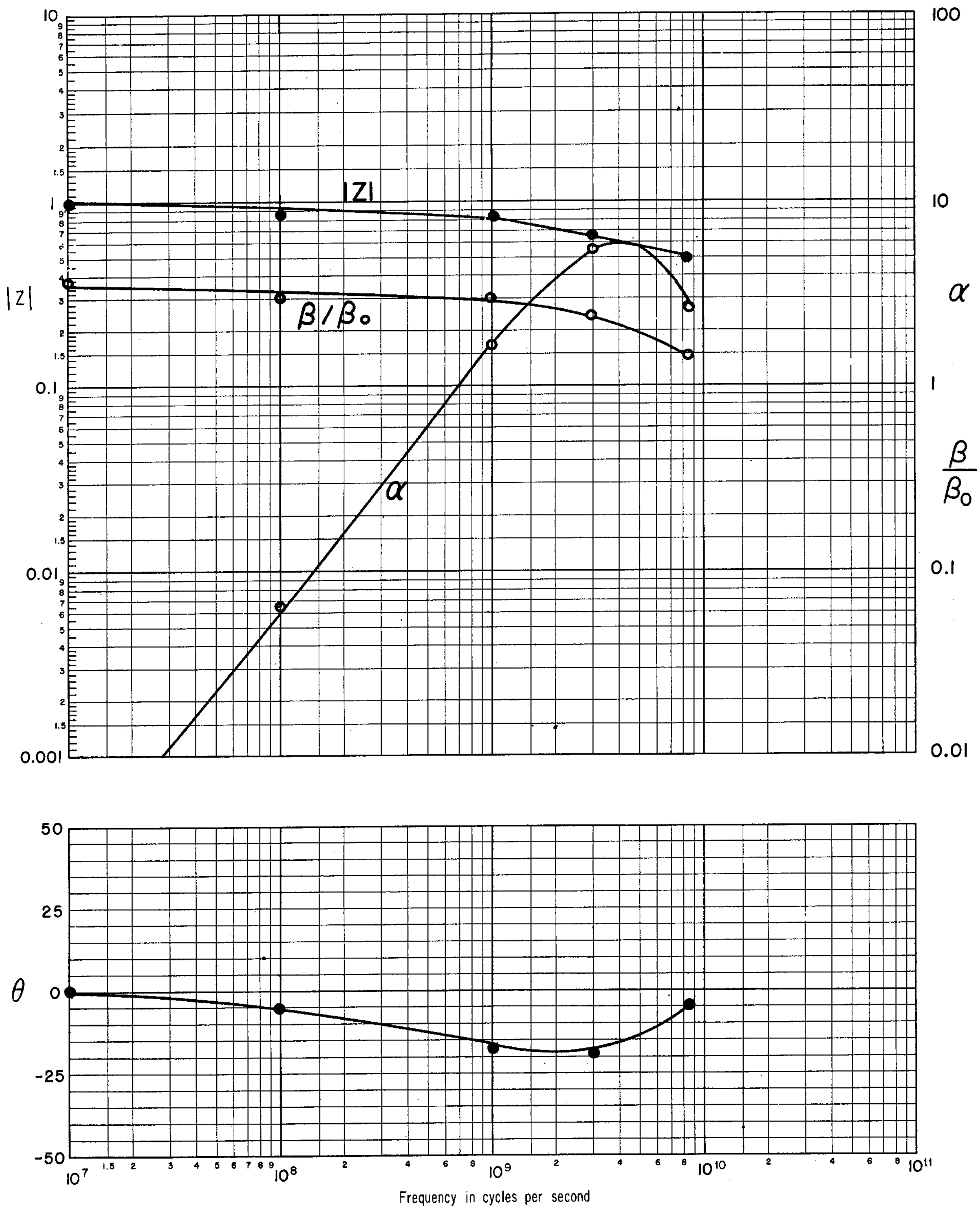
"Ferramic" J

General Ceramics



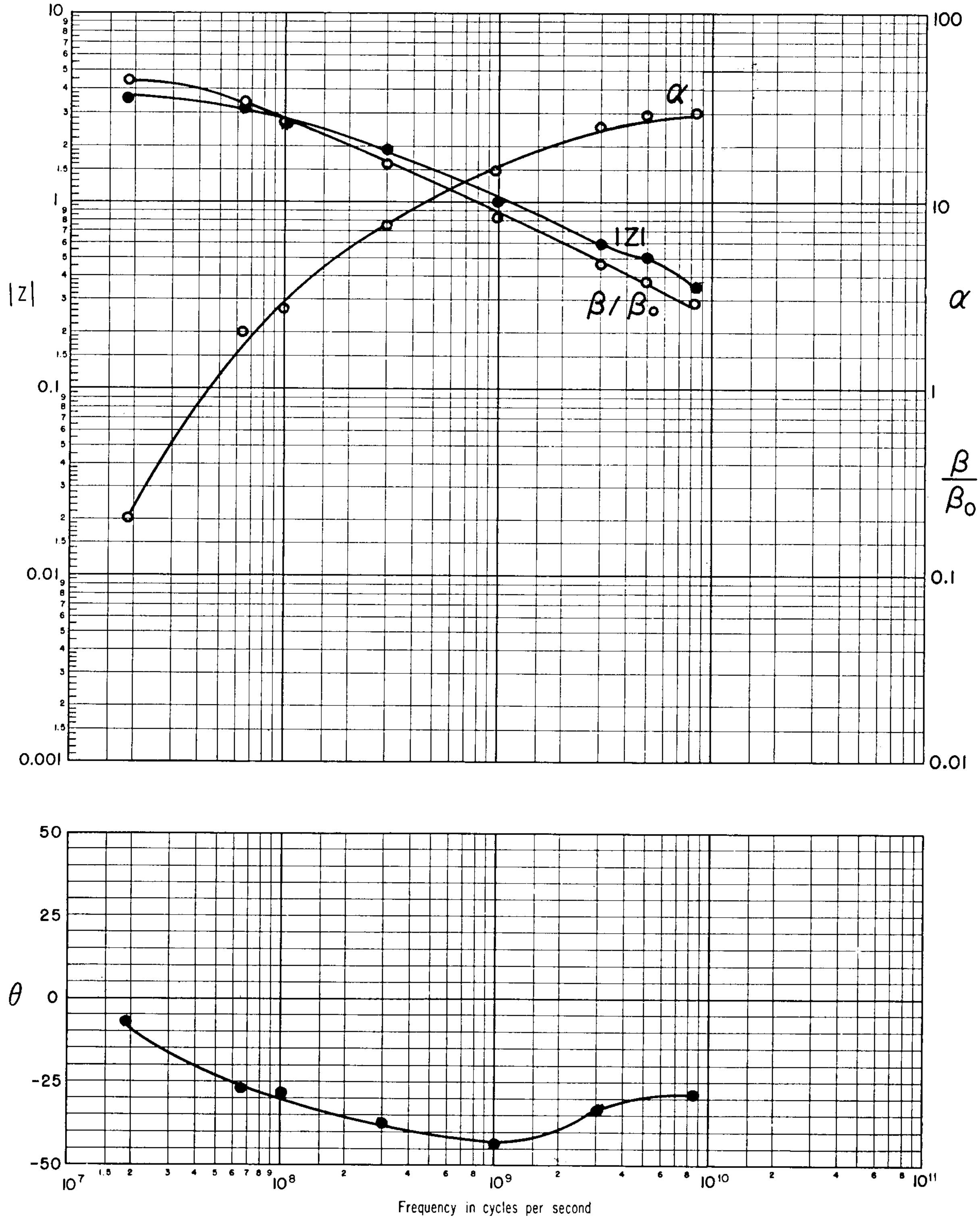
"Ferramic" K

General Ceramics



V A. Ferrites

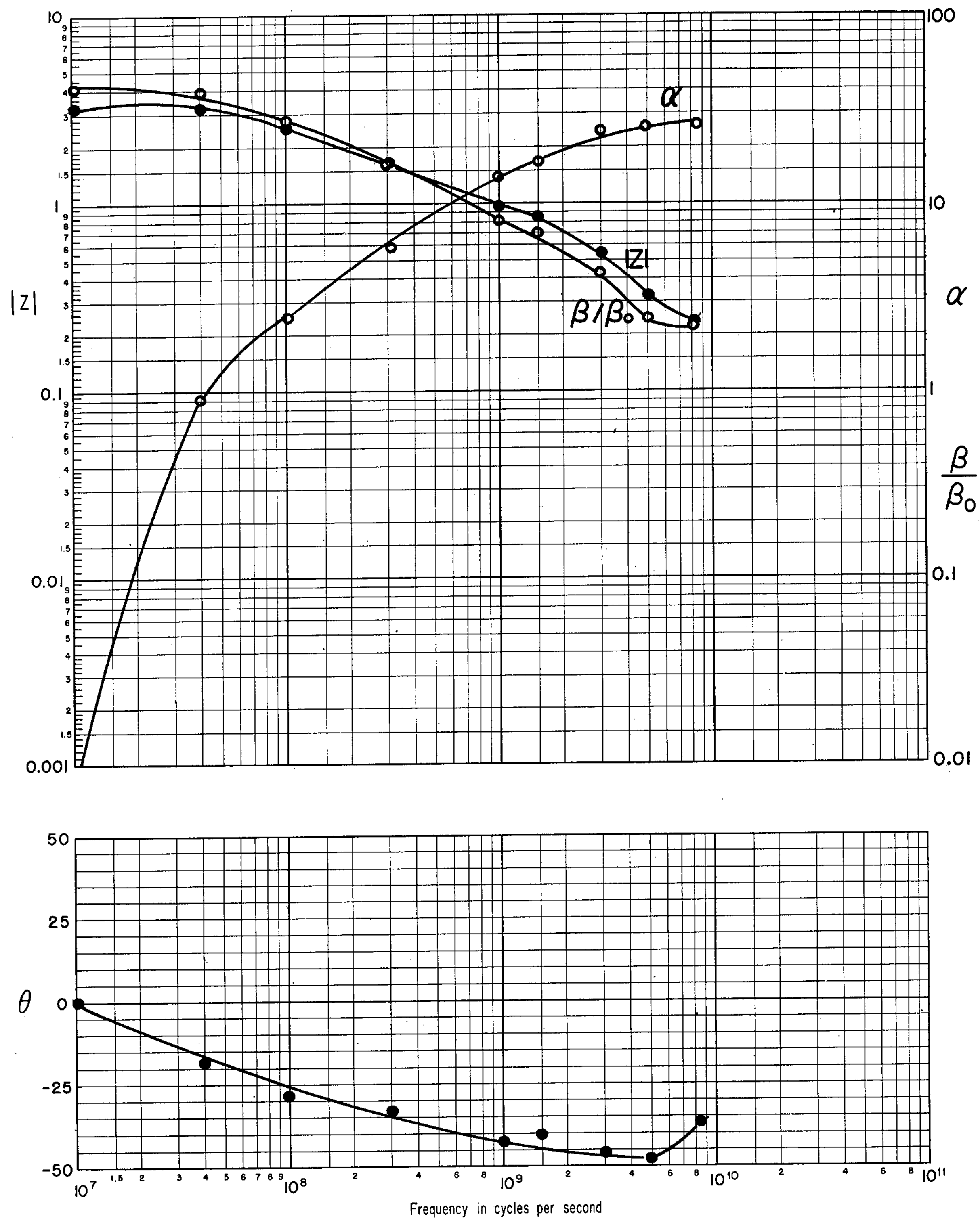
"Ferramic"Q (rec'd Dec. 1953) General Ceramics



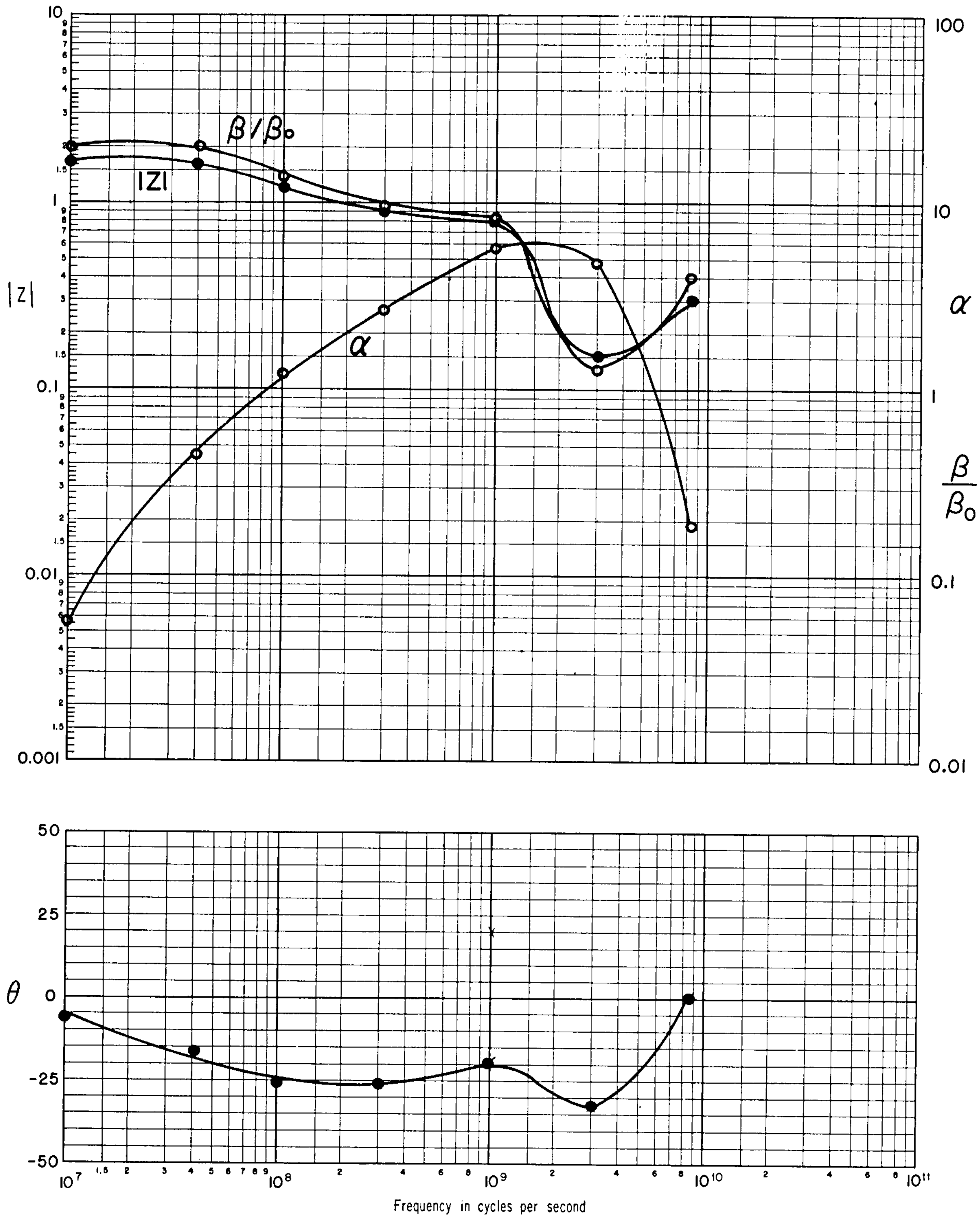
V A. Ferrites

"Ferramic" Q (Aug. 1954)

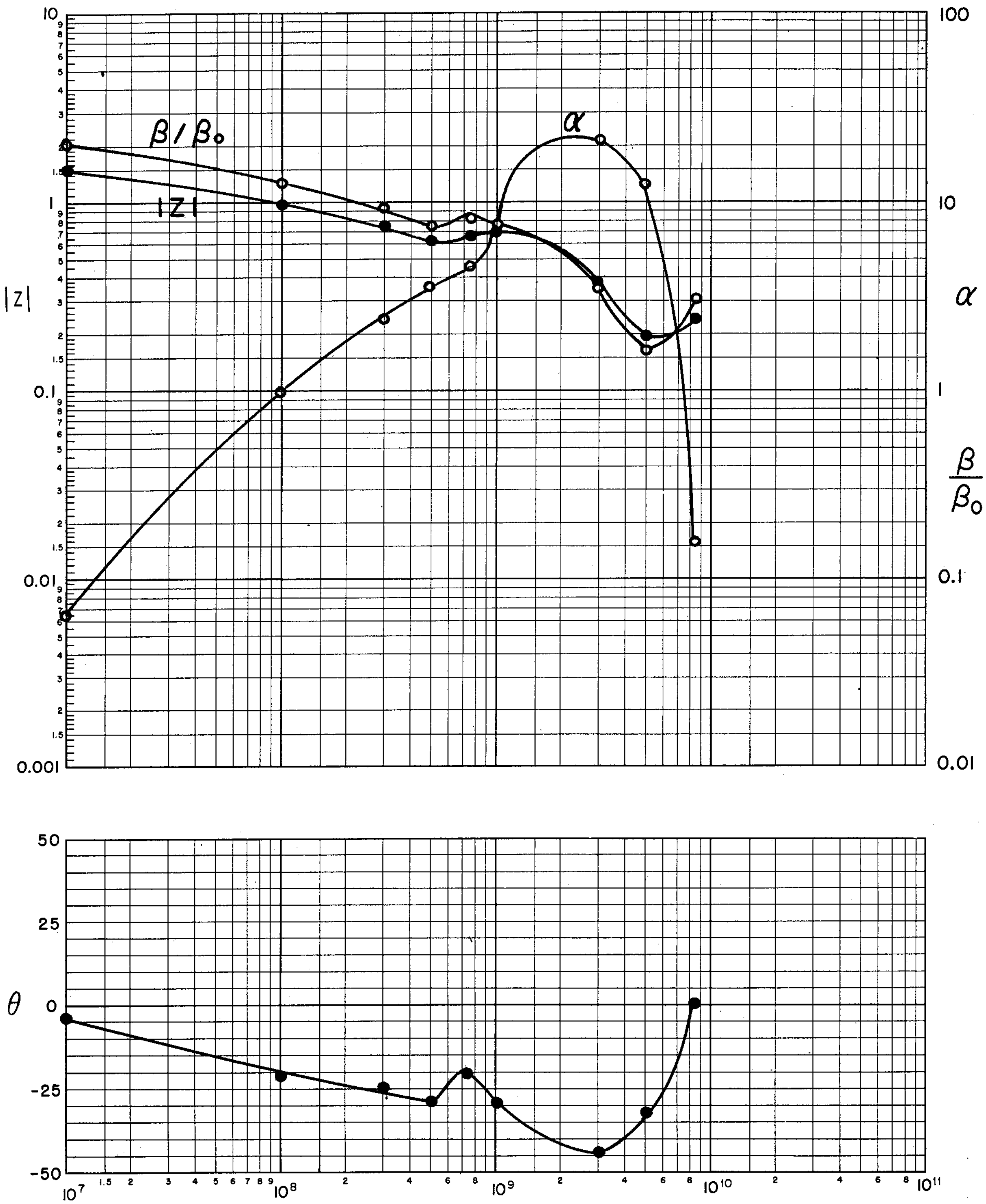
General Ceramics

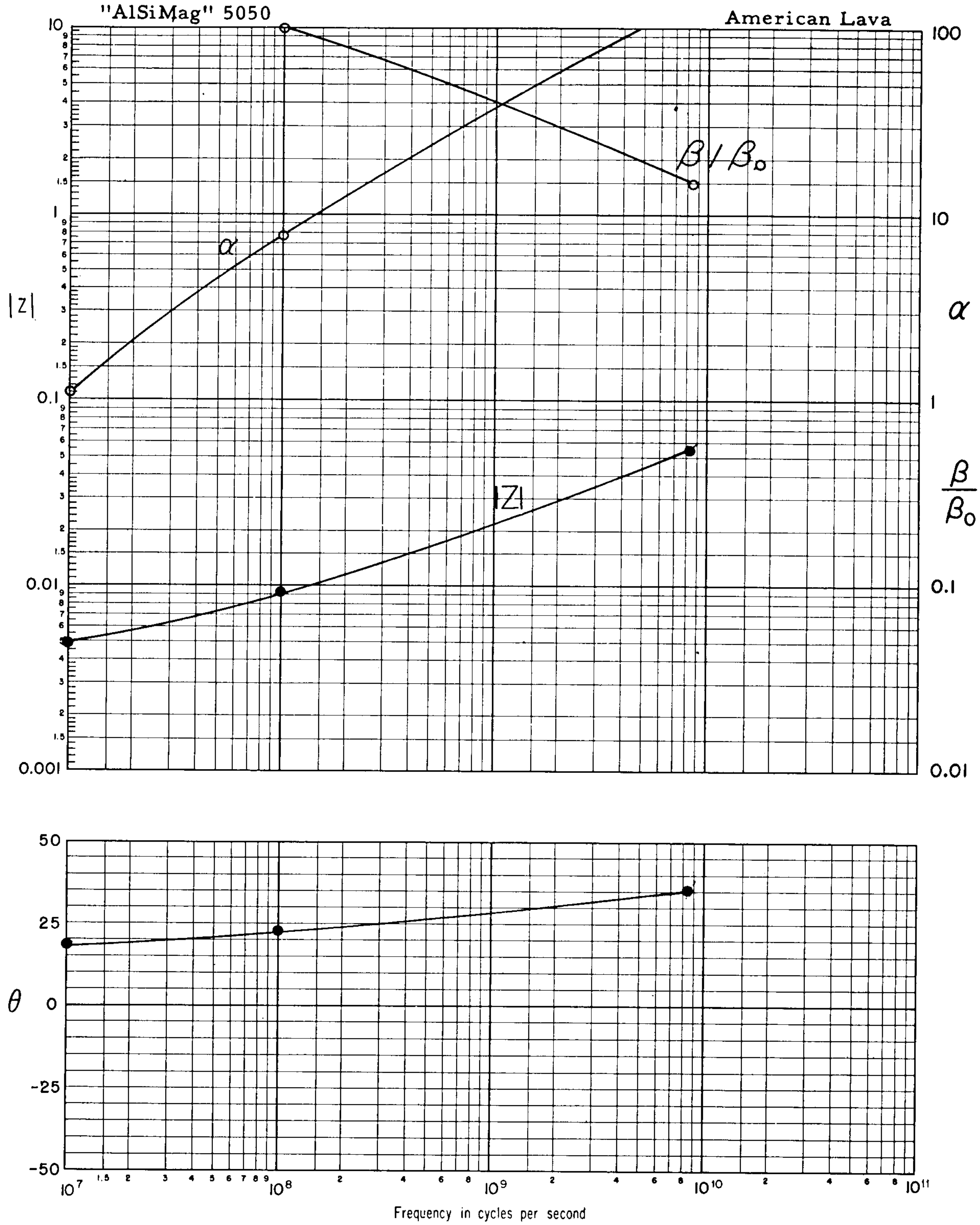


"Ferramic" 1118 General Ceramics



"Ferramic" 1331 General Ceramics

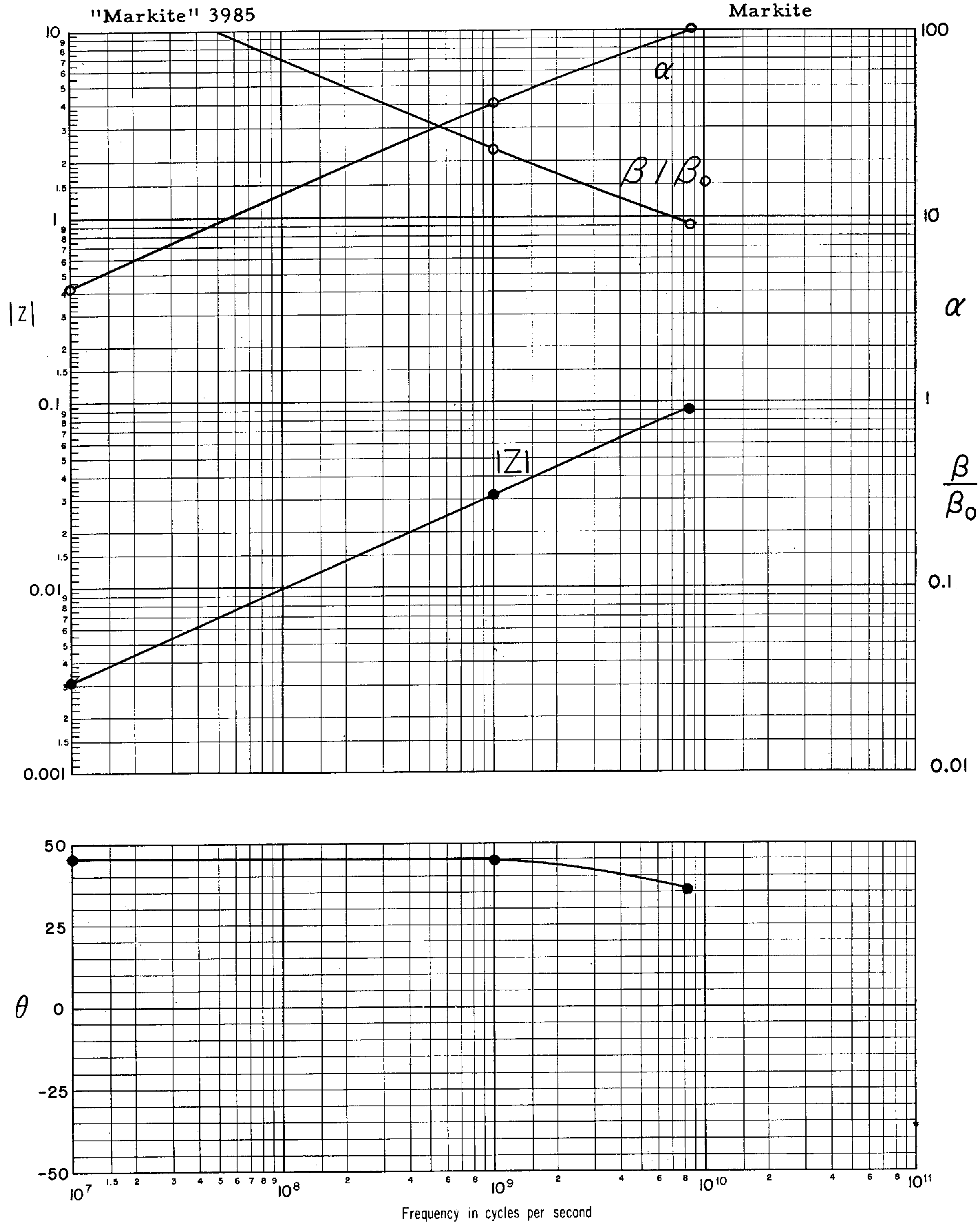



"AlSiMag" 5050
American Lava
10
1
0.1
0.01
0.001
|Z|
100
10
1
0.1
0.01
α
β/β₀
$\frac{\beta}{\beta_0}$
α
|Z|
50
25
0
-25
-50
θ
10^7
10^8
10^9
10^{10}
10^{11}
Frequency in cycles per second

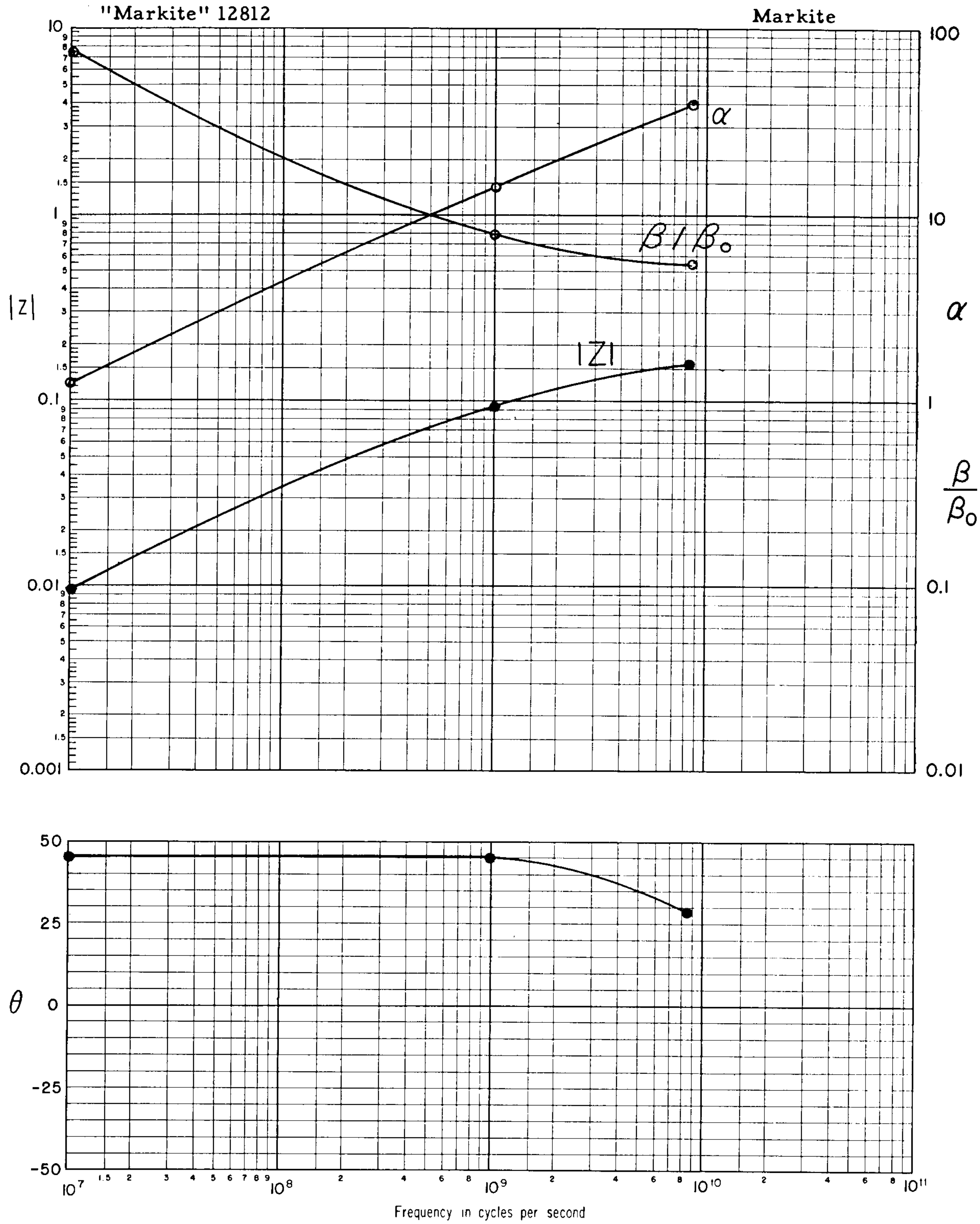
V A. Conducting Plastics

"Markite" 3985

Markite

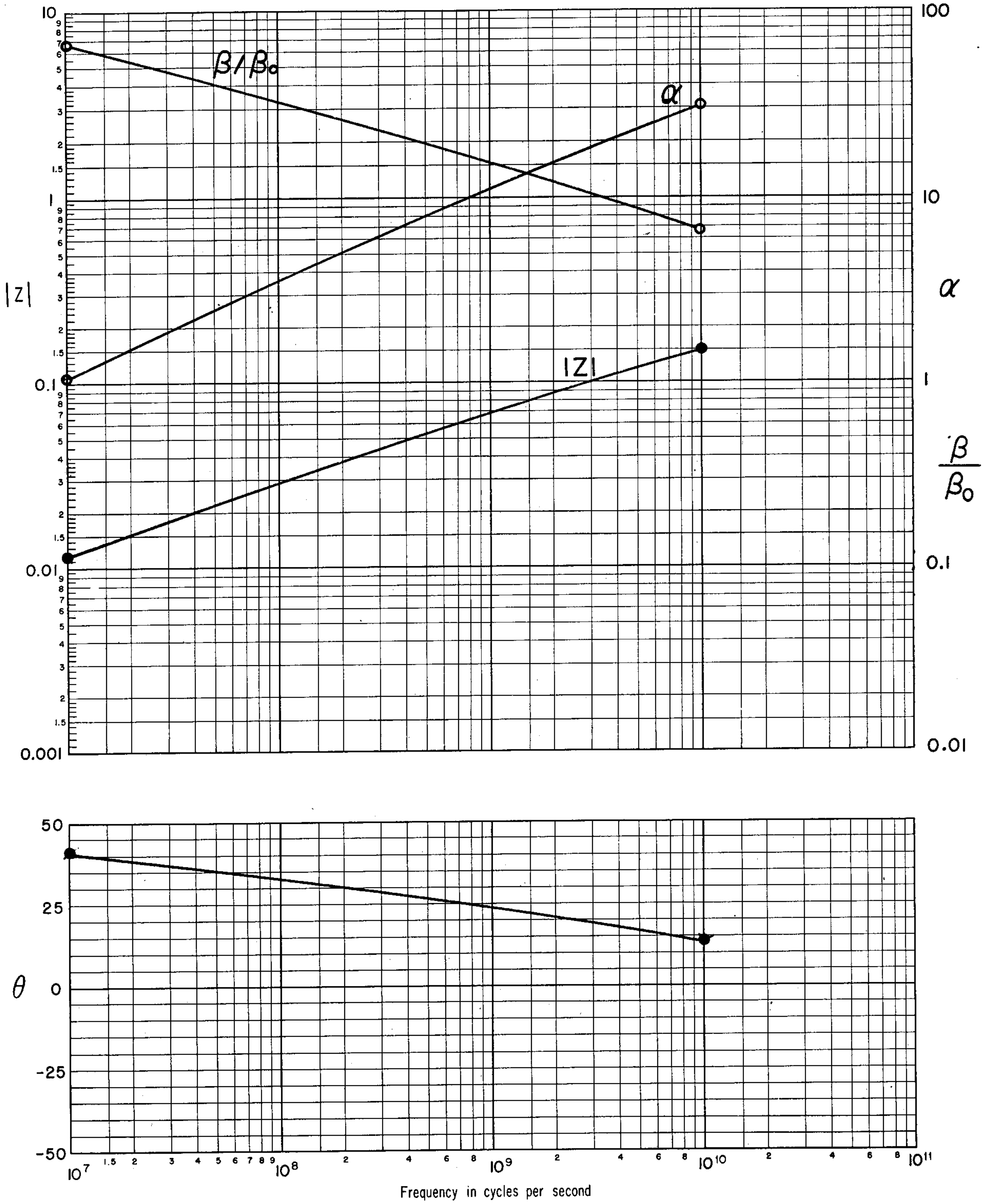


V C. Conducting Plastics



"Eccosorb" HF X122
(43.6% Graphite, 56.4% Polyester Resin)

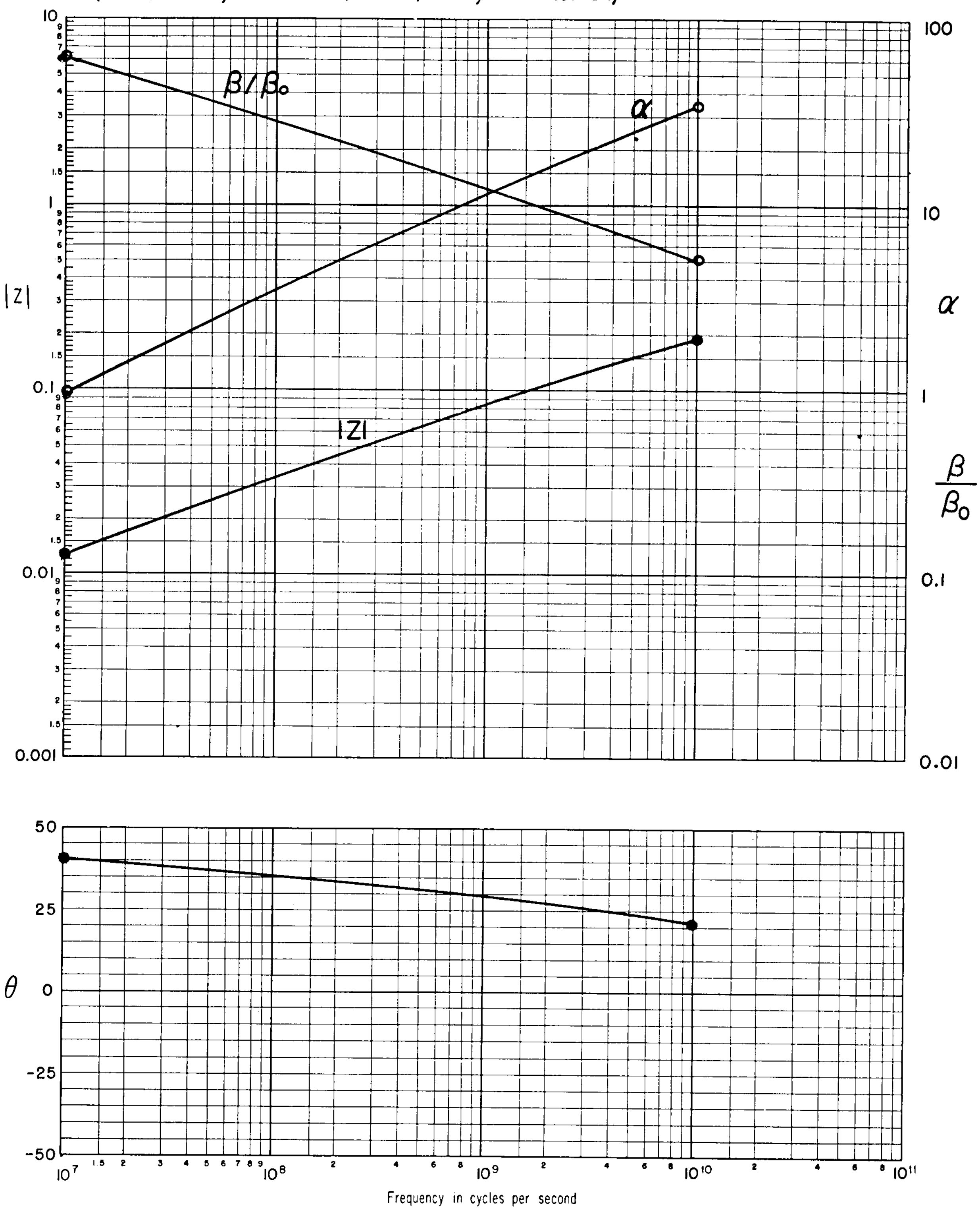
Emerson and Cuming



V D. Carbon-Plastic Mixtures

"Eccosorb" HF X123
(16.2% Acetylene Black, 83.8% Polyester Resin)

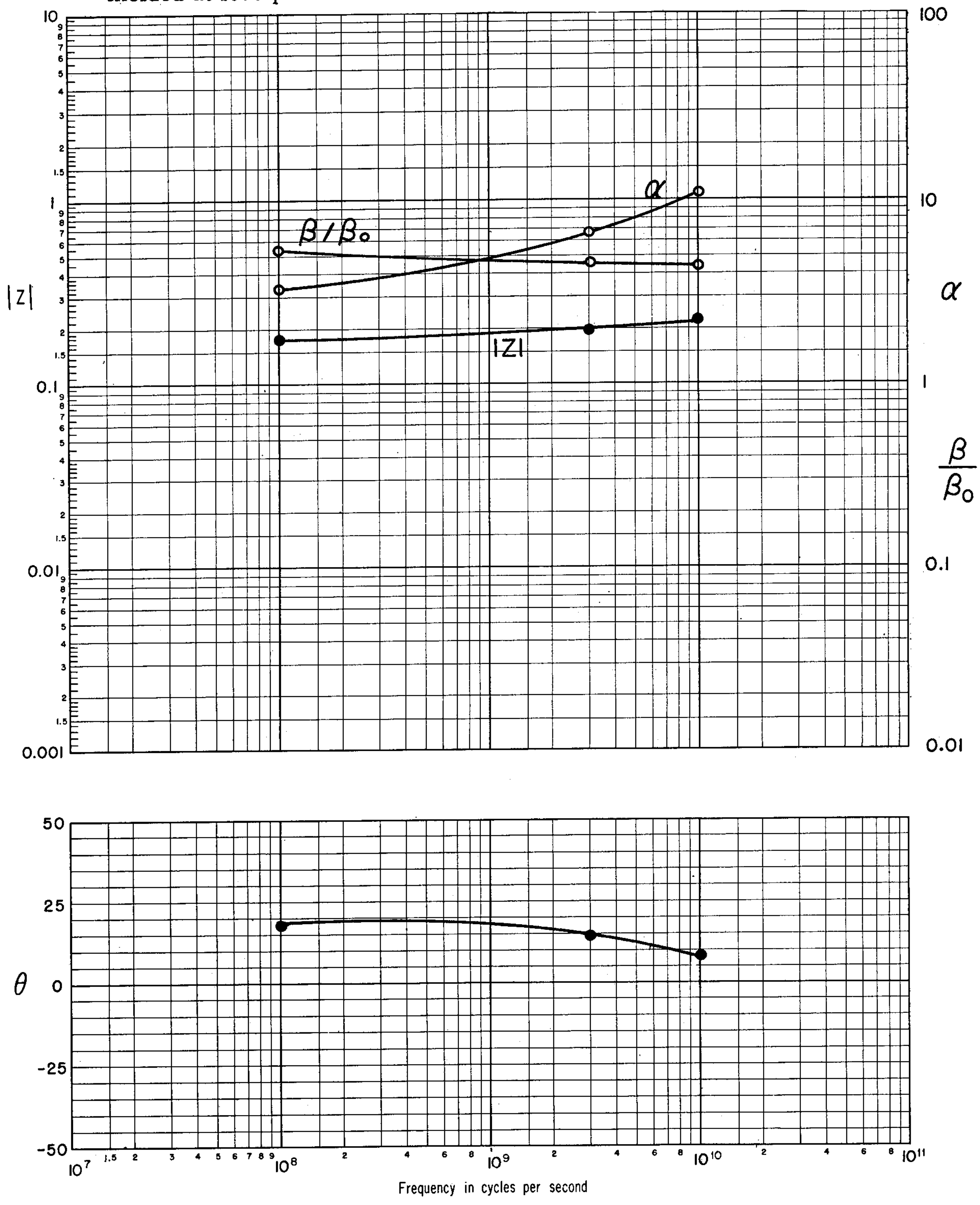
Emerson and Cuming



V D. Carbon-Plastic Mixtures

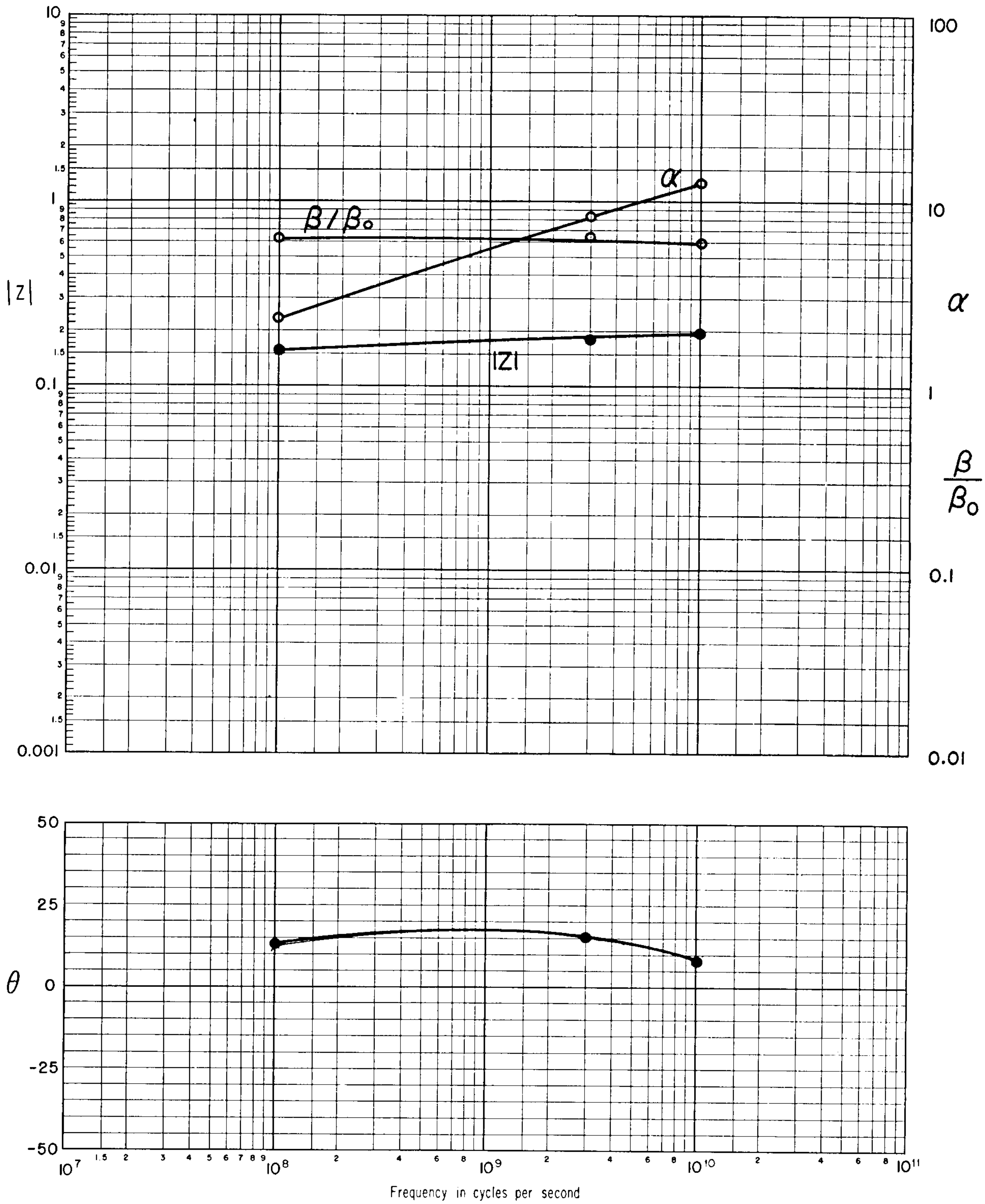
50% Polystyrene, 50% Carbon (Cabot's no. 9) molded at 1000 psi

Lab. Ins. Res.



V D. Carbon-Plastic Mixtures

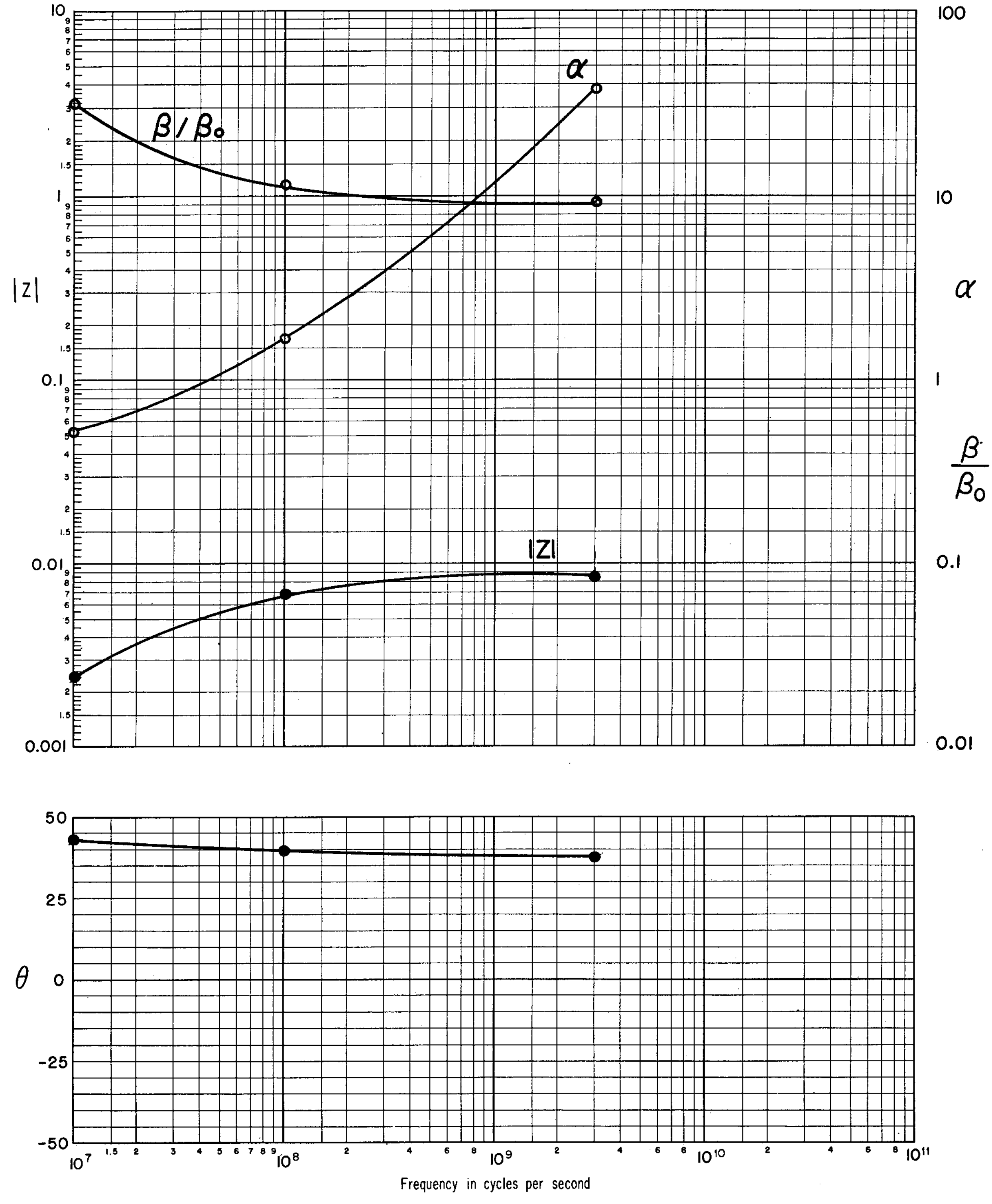
50% Polystyrene, 50% Carbon (Cabot's no. 9) Lab. Ins. Res.
molded at 10, 000 psi



"Chemelac"M1414
(75%"Teflon," 25% Graphite)

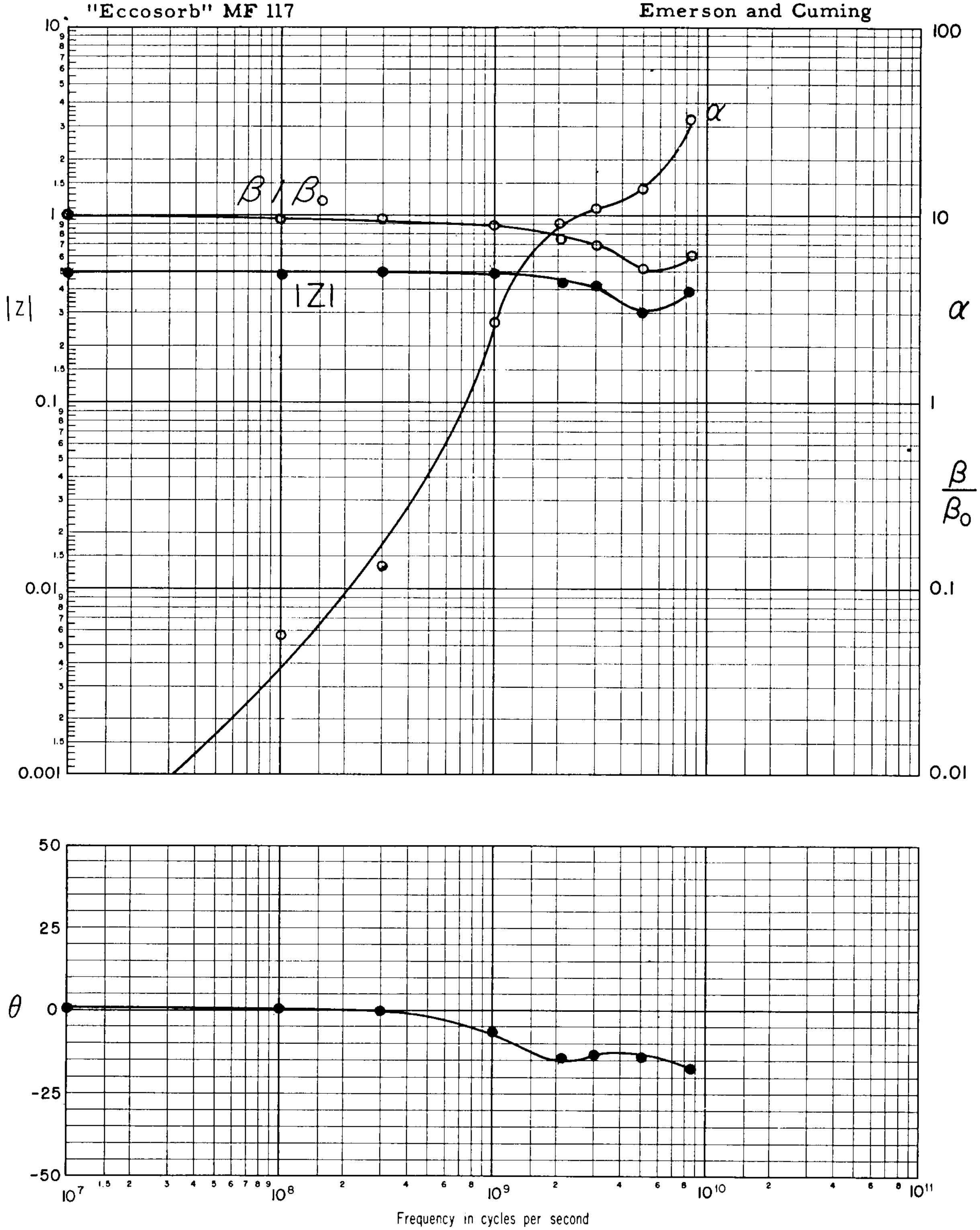
V D. Carbon-Plastic Mixtures

U. S. Gasket



"Eccosorb" MF 117

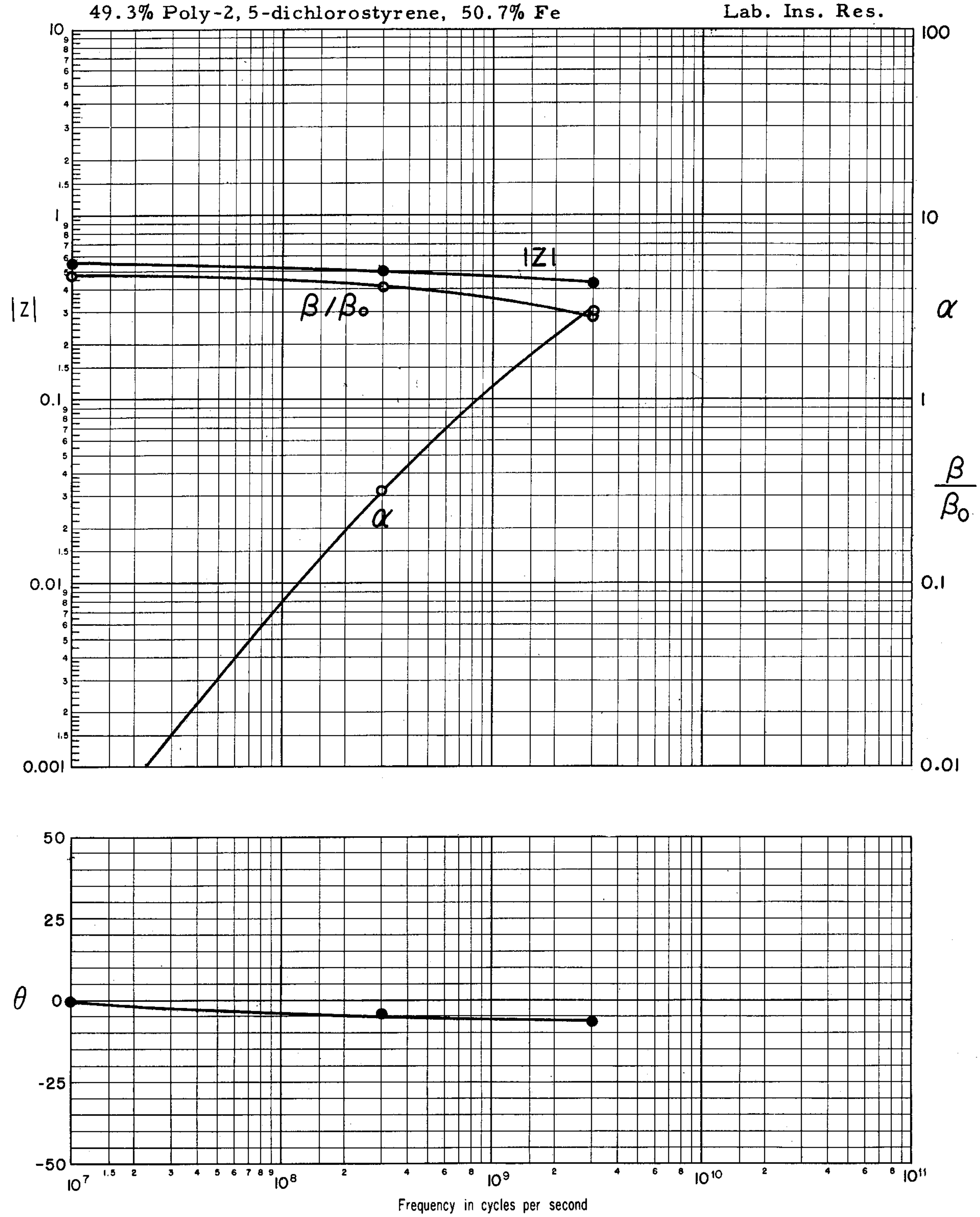
Emerson and Cuming



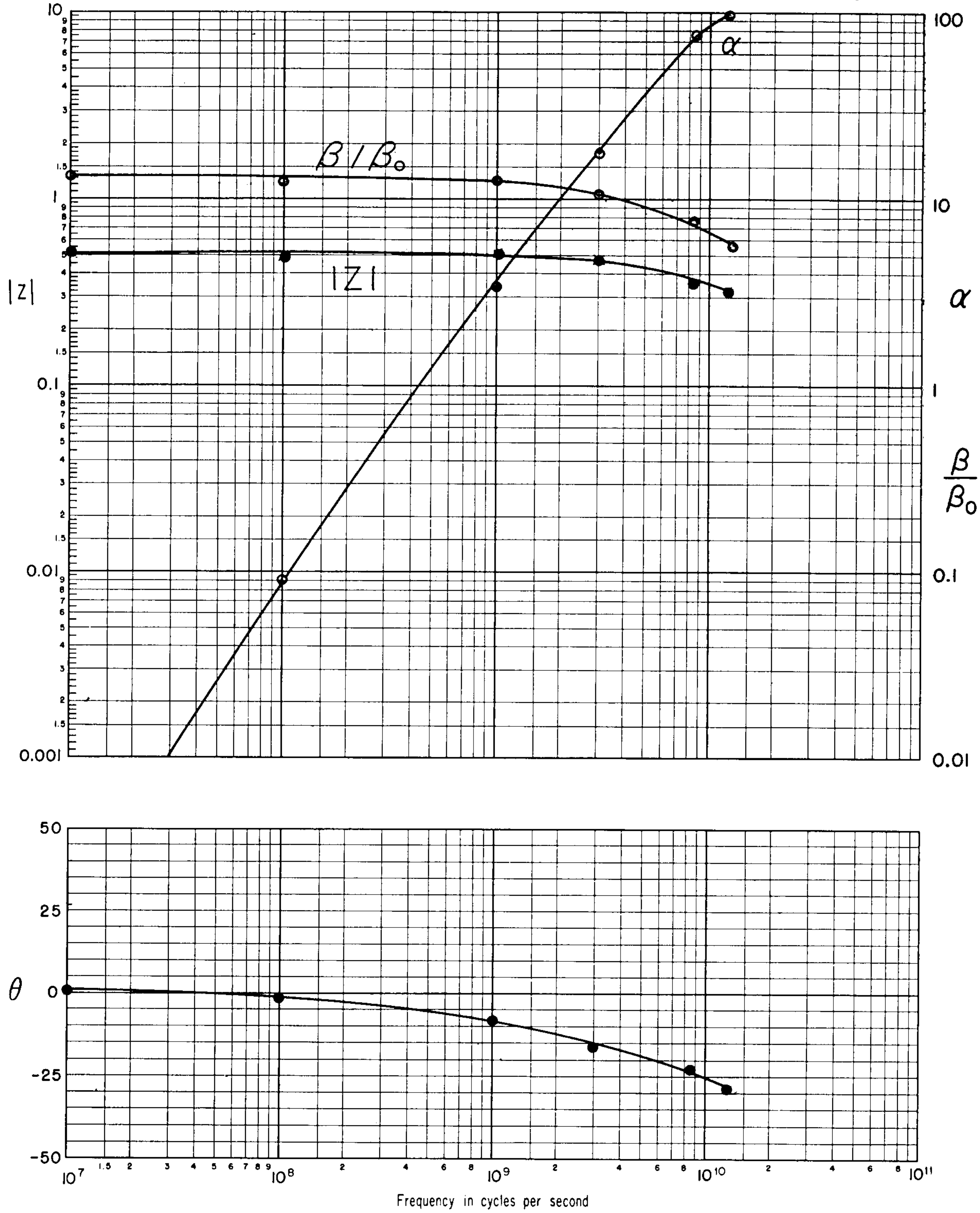
V E. Magnetic-Plastic Mixtures

49.3% Poly-2, 5-dichlorostyrene, 50.7% Fe

Lab. Ins. Res.



"Ferrotron" Core Material, Type 119 Polymer Corp.



Company Index for Vols. IV* and V

* Add 301 to Vol. IV page numbers to find corresponding page in "Dielectric Materials and Applications," A.R. von Hippel, Editor, The Technology Press, Mass. Inst. Tech., and John Wiley and Sons, New York, 1954.

Company Index (cont.)

Company Index (cont.)

*Now The Borden Co., Chemical Div., Dept. T-56, 350 Madison Ave., New York 17, N.Y.

Company Index (cont.)

* Now Celanese Corp. of America, 290 Ferry Street, Newark 5, N.J.

Company Index (cont.)

Company Index (cont.)

Company Index (cont.)

Materials Index for Volumes IV* and V

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* Add 301 to Volume IV page numbers to find corresponding page in "Dielectric Materials and Applications," A.R. von Hippel, Editor, The Technology Press, Mass. Inst. Tech., and John Wiley and Sons, New York, 1954.

Materials Index (cont.)

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